DISCOVERY

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ST LAWRENCE SEAWAY

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Editor
Anthony R. Michaelis, PH.D., B.SC.

Editorial Office
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CHAncery 6518

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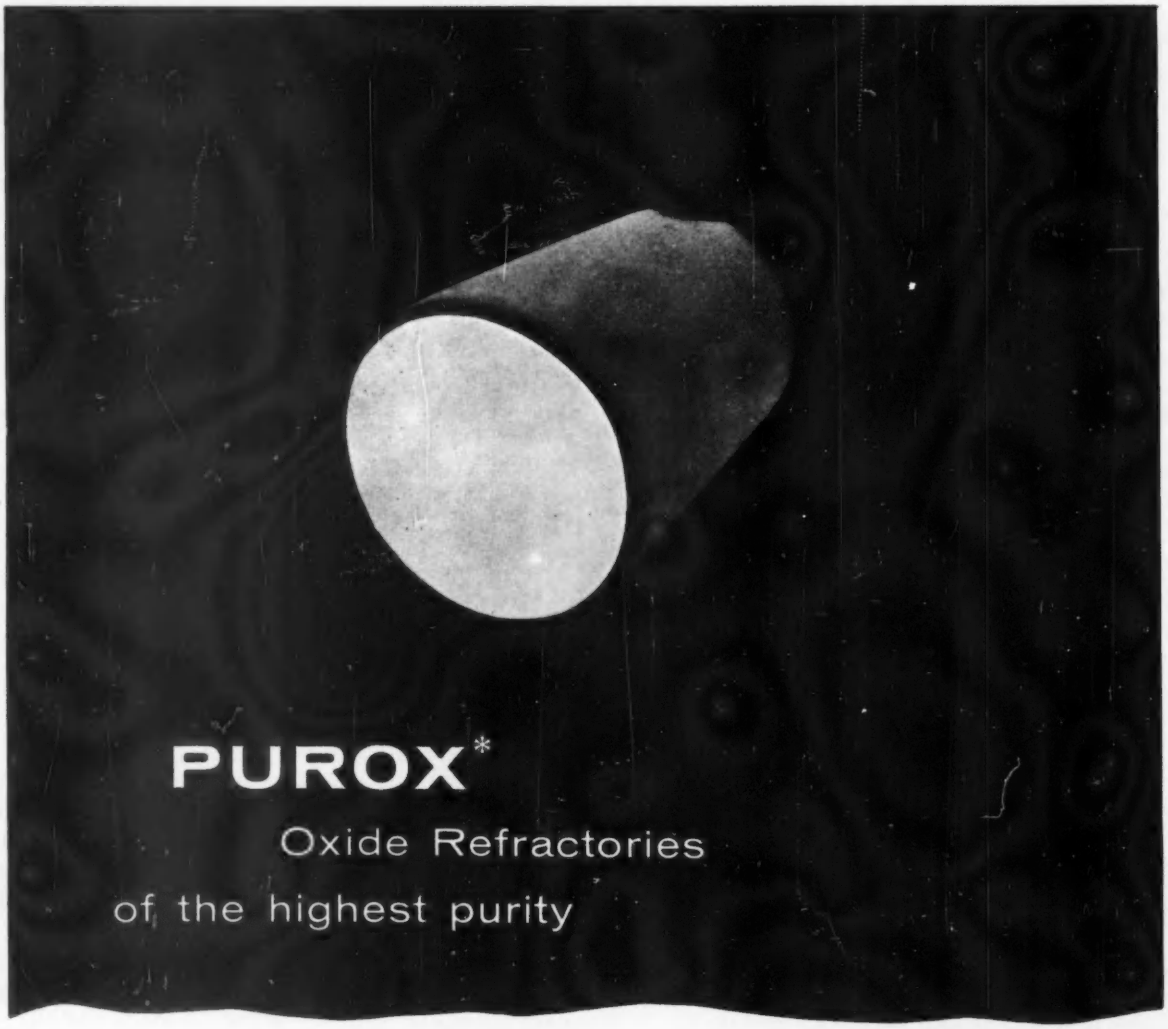
OUR COVER PICTURE

The St Lawrence Seaway will be officially opened this month by Her Majesty the Queen and President Eisenhower. Above is the Iroquois Lock, which carries shipping around the Iroquois Dam (*background*). The dam is one of the principal structures of the new St Lawrence Power Project (See p. 244).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THE PROGRESS OF SCIENCE

BRITISH SPACE RESEARCH

The recently announced decision of the British Government to make several hundred thousand pounds available for space research will be welcomed by all who are truly interested in expanding our small knowledge of the regions beyond our own atmosphere. In spite of the much-publicised American and Russian satellites, the total new information which has so far been obtained is still extremely little; it could hardly be anything else when the difficulties of telemetered research and the vastness of unexplored space are taken into account.

At present it is hoped that British-built instruments, a task that may well take a year or so, will be taken into space by American rockets. The decision to invest large sums of money, in the order of 10 to 20 million pounds, to launch British space rockets, has been shelved for the time being, and so, apparently, has the field of animal experimentation.

It is, of course, quite obvious that with the means at present at their disposal, British scientists will be quite unable to wrest the lead from their American or Russian colleagues. But that is not to say that with careful planning and attention to detail valuable research results cannot be obtained. String and sealing-wax have proved useful research tools in the past; if they can still do so remains to be seen. The most hopeful aspect of Britain's entry into space research is the simple fact that co-operation within the Commonwealth and European countries can now begin in earnest. If Britain can now give a practical lead for international co-operation in space research, through COSPAR or the United Nations, then indeed the microscopic sum of money devoted to British space research may yet pay handsome dividends.

TOWARDS A SCIENCE OF DEFENCE

"The whole art of war is being transformed into mere prudence, with the primary aim of preventing the uncertain balance from shifting suddenly to our disadvantage and half-war from developing into total war."

Since, unhappily, science has recently played a more active part in the development of weapons of mass destruction than in any other field of human activity, it is reassuring to recall this dictum of Clausewitz (1780–1831) and to be reminded of the object of a defence policy. Of course, the relationship of science to defence raises many considerations—the balance of scientific effort between civil and military purposes, the effectiveness with which scientific innovations are introduced within the services, and the extent to which scientists are consulted in policy-making. But these vital questions are overshadowed by an even greater one—the degree to which science as a philosophy and method is applied to an understanding of war and defence, their objectives, and their conditioning effect on the evolution of society.

While it is of the greatest importance to an effective defence system to ensure the maximum application of science, the all-transcending problem is to apply the scientific method to an operational study of the impact of the latest weapons on the actual nature of war, and through this, of the repercussions of the required pattern of our defence programme on the economy and society. Despite high-powered thinking, this area is shrouded in obscurity. Thoughts on the Deterrent are incredibly confused and divergent: its potential to inflict absolute destruction, or to bring complete victory are stressed by its opponents or advocates respectively, but assessments of how far it is a valid "chess-piece" to achieve just that balance of opposing forces required by a logical defence policy are inconclusive. Is, for instance, the possibility that the radiation involved in a full-scale thermonuclear bombardment is beyond the threshold of safety a factor nullifying the Deterrent, not merely for Britain with its high population density, but the U.S. as well? Again, what of the practicability of tactical nuclear weapons? Some authorities quote the theoretical results of Exercise "Sage Brush" in Louisiana and "Carte Blanche" in Germany as proving that the degree of destruction involved is insupportable, and hence disqualifies them from use, yet Lieut.-General Gavin, late Chief of Research and Development in the U.S. Army, in a remarkable book,* outlines the type of army division which theoretical evidence suggests could survive an atomic bombardment in the field. Granting his thesis for the time being, there remains a whole series of problems relating to dispersal, mobility, and not least, control, all of which require the severest operational analysis, and solutions of which are prerequisites for waging anything approaching a "push-button" war. Moreover, the further the analysis is pushed, the closer do the present opposing defence schools (pacifists aside)—the advocates of a return to conventional warfare, and those who see defence policy in terms of nuclear weapons—move towards a possible reconciliation. Both are convinced that defence policy can no longer be viewed in isolation or in relation to individual weapons, but in terms only of the widest economic and political considerations. The nuclear school increasingly accepts that the limiting factor is the mind of man itself, the process of decision-making and the lead-times, not least in the democracies, for the development of a particular technological defence pattern; nor is it any longer unmindful that in a situation where the most advanced weapons give their possessor comparatively little leverage, political changes in uncommitted areas can tilt the balance decisively to one side or the other. Hence the importance of both psychological warfare and economic aid.

However, it is in his discussion of war and space that General Gavin is most effective. President Eisenhower's celebrated statement: "Earth satellites in themselves have no direct present effect upon the nation's security" is conclusively rebutted. There can be no doubt that if the present missile race continues, the Great Powers will be driven into space for specifically military reasons. The prospects of a space race and ultimately space war are immediate rather than fantastic.

* "War and Peace in the Space Age", Hutchinson, 1959.

A NEW THEORY OF LIQUIDS

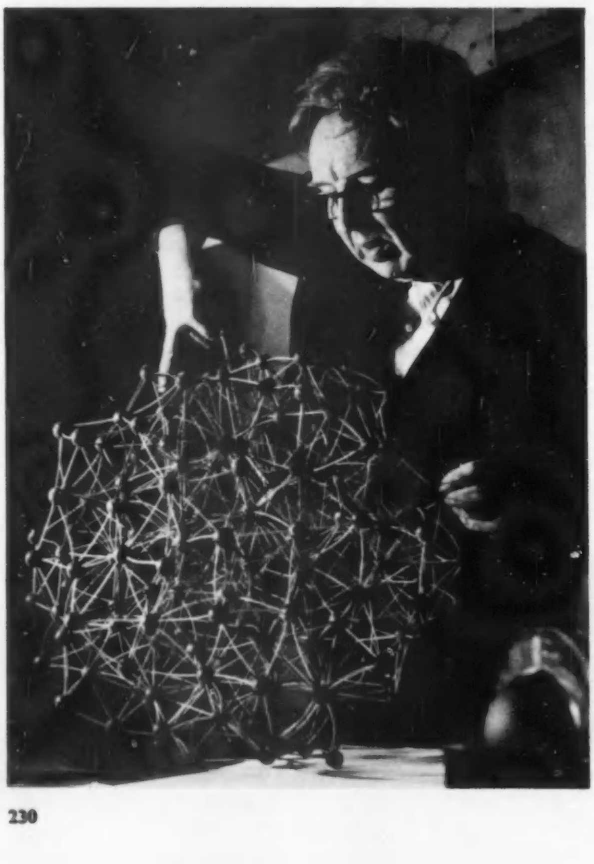
We know why a solid is a solid, and a gas is a gas. But why is a liquid a liquid? This seems a strange question to pose about a material with which we are all so intimately familiar, but there is no satisfactory theory in terms of molecular structure which can tell us why. It is true that a liquid is like a solid in having a density that is only 10%, or even less, different. But it differs absolutely in having no rigidity. It flows. The energy content of a liquid is also very similar to that of the solid from which it is derived, although its entropy is very much greater.

In a solid, every atom is surrounded by other atoms acting in the same way precisely as millions of other atoms, all regularly placed. It is long-range order. In contrast, in a liquid there is no long-range order. No molecule is in a similar situation to any other.

How can this irregular arrangement be understood and described? Prof. J. D. Bernal, F.R.S., Crystallographer and Head of the Physics Department at Birkbeck College, University of London, in an evening discourse to the Royal Institution on October 31, 1958, stated his attempt at a solution to this problem. This lecture is here summarised by Maurice Goldsmith.

Stuck in a fogbound Moscow airport in 1932 with the mathematical physicist, W. H. Fowler (son-in-law of Lord Rutherford), they began to talk about water. It was then that Bernal first formulated a general theory in which he tried to explain the structure of water in terms of the arrangement of molecules. It was published the following year and is known as the Bernal-Fowler Theory. In 1936 he published a paper in which he extended the theory to cover other liquids. Then for two decades, occupied first with proteins and then with war, he gave it little thought.

Prof. Bernal constructs by hand a physical model of a molecule of liquid.



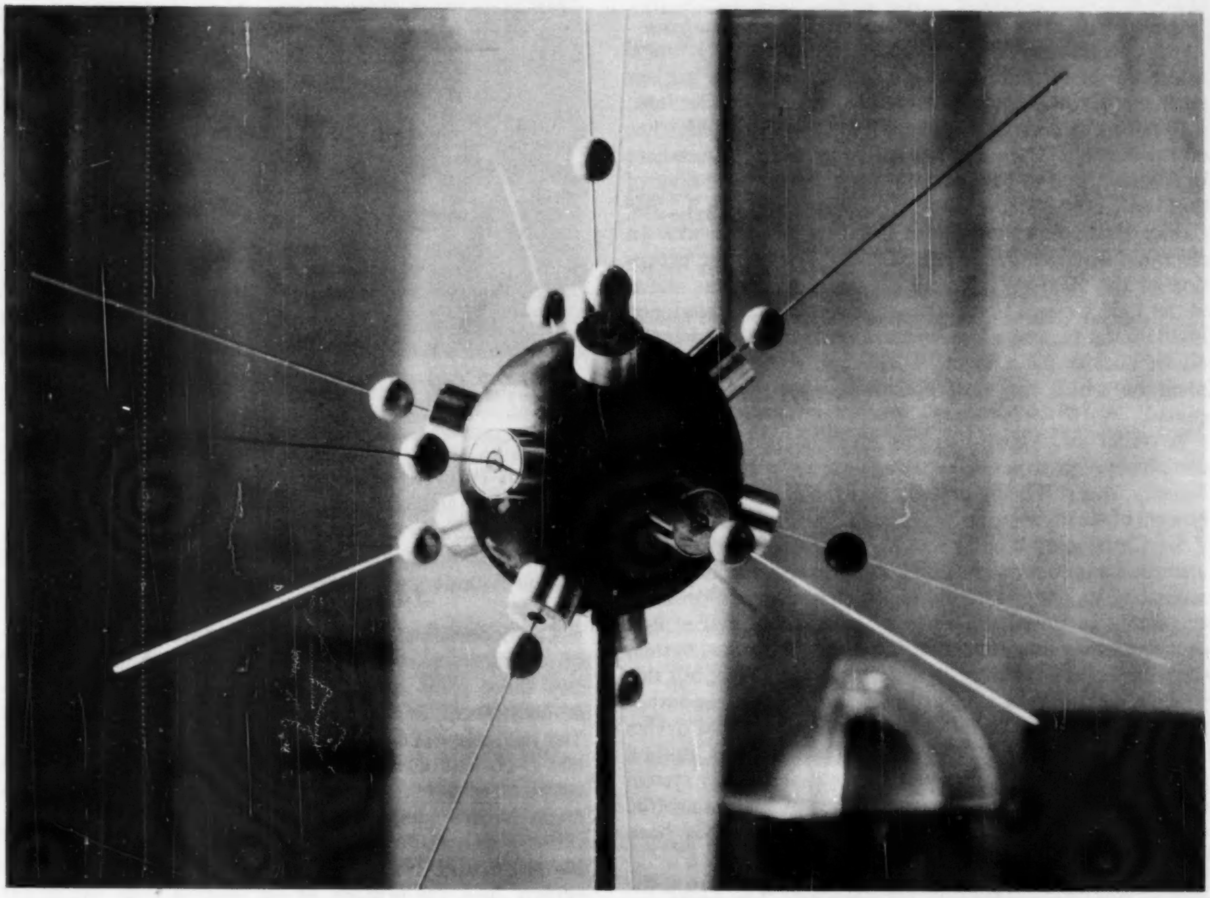
What had held him up was that although he realised the irregular nature of liquids and the relationship of this to their physical properties, he could find no means of describing them adequately. A few months ago, however, he was listening to a lecture by Prof. F. C. Frank, F.R.S., of the University of Bristol, on the structure of some complex metallic alloys in which he made use of the concept of the linking of polyhedra of twelve to sixteen corners. This was seized on as a possible clue in helping to find the arrangement of molecules in liquids.

To study the nature of irregular aggregates, so different from the crystals with which he is familiar, Bernal built a model in which the distances between the molecules were allowed to vary from 10% below to 30% above the average distance in a regular arrangement. This model fitted well with the volume and energy content of liquids, but was open to the objection that it had been constructed deliberately. The next task, therefore, was to see whether a dense irregular structure could be formed by a purely random method. This was attempted by means of an adjustable model in which an ideally random arrangement of balls in space could be transformed step by step into one in which the maximum admissible distances between the points could be achieved without introducing any regularity. These models could be used later for programming computers.

Meanwhile, a plausible solution was arrived at by much cruder methods. The packing of jumbled equal spheres was taken as a model for a liquid arrangement. A football was filled with balls of Plasticine rolled in chalk-dust. The compression enabled one to see what the pattern of irregularity was. It simply brought out as polyhedra the mutual arrangement of the spheres. The commonest face in all the polyhedra is the pentagon, and this is the clue to the structure of liquids. Regular three-dimensional arrangements have symmetries limited to multiplicities of 2, 3, 4, 6. Fivefold arrangements can occur only in very complex crystalline structures. The central thesis is that irregular dense packing of pentagonal arrangements are necessarily connected.

Bernal has worked out all the possible arrangements of spheres up to twelve, all touching one equal central sphere. More than half of these have predominantly pentagonal arrangements, and these are the only ones found among the Plasticine polyhedra. No two of these had exactly the same arrangement of faces. In contrast to this heterogeneous arrangement, that based on identical hexagonal packing is 10% more compact and consequently leads to a rigid and far more stable structure. The fluidity of a liquid, then, is a consequence of its molecular irregularity because its molecules can easily change from one irregular configuration to another, which those in a solid cannot do, having only one stable configuration.

In the liquid state there is a specific kind of neighbourly relation, patterns of five are being formed and re-formed continuously, very much as when in a crowd an individual keeps always in touch with a few other persons but these others are not the same. The absolute structural distinction between the hexagonal solid and the pentagonal liquid is



An apparatus devised by Prof. Bernal to enable him to determine the distance between the elements that go to make up a molecule.

(*Photographs by Peter Keen*, The Observer)

that there is always a sharp melting-point and no possibility of a gradual change between them. Bernal has also considered the relation of liquids and gases. Wishing to bring himself up to date with work on the properties of liquids, he consulted Prof. R. C. Jones, of Queen Mary College, University of London, who had been studying the properties of the most simple and ideal liquid—argon.

Prof. Jones had shown in a paper on the transition between liquid and gaseous argon that not only, as had previously been known, at the critical point but also at higher pressures there is a sharp transition, marked by high specific heat, which separates liquids from gases. An explanation of these phenomena relates them to the variation of configuration of molecules with the temperature. At low temperatures there are ten to twelve close contacts between each molecule and its neighbours. As the temperature rises, the number of contacts falls to three, and this increases the volume of the liquid threefold. This corresponds exactly to the degree of expansion of all simple liquids up to the critical point, which is, according to Bernal, the limit of coherence of the liquid. He interprets the specific heat maximum of Jones as a change from a loose but coherent arrangement of molecules to an incoherent arrangement of clumps of molecules. In other words, above the "hypercritical" temperature the liquid structure becomes incoherent, consisting of associated groups of molecules free to move in space. Below and above this key temperature, the number of inter-molecular links does not change noticeably.

The conclusion from this is that everything we have learned in textbooks about the unity of the fluid state above the critical point can no longer be accepted. A gas and a liquid do not form a single fluid phase. Each is a distinct state of matter, although one may pass into the other without visible discontinuity. This is probably a very general phenomenon applying not only to all liquids and gases but also to all conditions of critical mixtures. The road from a solid to a liquid to a gas in terms of molecular structure is therefore from the close-packed regular coherent to the close-packed irregular coherent, to loose incoherent bundles of molecules, and then to completely free molecules.

If the picture Prof. Bernal is showing proves to be closer to reality than the more formal ones of previous workers, then there will be practical applications in the fields of refrigeration, gas-liquid separation, and the flow of liquids.

REFERENCE

Nature, January 17, vol. 183, p. 141.

CALDER HALL SETTLES DOWN

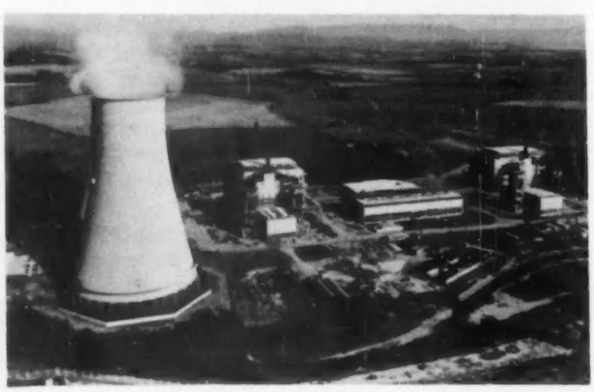
At the present time there are four locations in the world where power for public use is being generated by nuclear means: a 5000-kW plant just outside Moscow, at Obninsk; a 100,000-kW plant stated at the 1958 Geneva Conference on the Peaceful Uses of Atomic Energy to be "somewhere in Siberia", and to have started operation in September of that year; a 60,000-kW plant at Shippingport, U.S.A.; and Calder Hall. Of these, Calder Hall is the largest, with an electrical export capacity of 152,000 kW. With the exception of the 5000-kW plant at Obninsk, which was stated at the 1955 Geneva Conference to have been commissioned in 1954, the famous plant on the Cumberland coast is the oldest nuclear plant in the world, and it is certainly the plant on which the most operating experience has been gained.

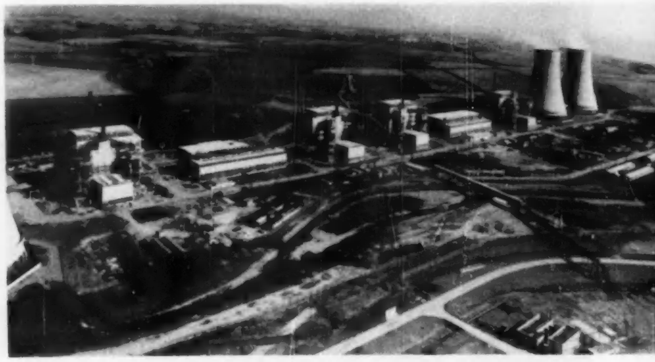
A recent visit showed us that all four reactors are now completely constructed, although the fourth unit, in January, was still being brought up to full load in a gradual process of steady increase of output.

Sir Christopher Hinton recently described Calder Hall's operating experience as "dull", since everything had gone according to plan. There was, of course, an unfortunate experience in June 1958, when the presence of chilled iron shot, probably used for sandblasting, in the steam system caused a turbo-alternator to suffer severe damage: but this was not essentially a nuclear plant failure, since the turbo-alternators and steam systems are of conventional design throughout. Otherwise the generation of over a million and a quarter units for the public electricity supply system and the production of a large quantity of plutonium (the exact figure is withheld, for security reasons) has been achieved with the minimum of incident.

One of the vital aspects of nuclear plant operation is the detection of burst fuel elements, and the method adopted at Calder Hall has proved completely reliable. Over the two and a half years of operation there have been about thirty damaged cartridges—a very small number. Some incidents have required that the reactor concerned should be shut down immediately, and the emergency release of the control rods into the core has been carried out without trouble. In other cases, the slight excess radioactivity detected in a particular fuel channel in the core has been watched carefully and the reactor allowed to stay on load for days or even weeks. It must be appreciated that at Calder Hall, unlike the later designed stations of the same basic scheme now being constructed, it is necessary to shut the reactor down and to discharge all the 25·9 tons of carbon dioxide coolant gas before a fuel element can be changed.

Calder Hall Nuclear Power Station, showing Calder B nearing completion.



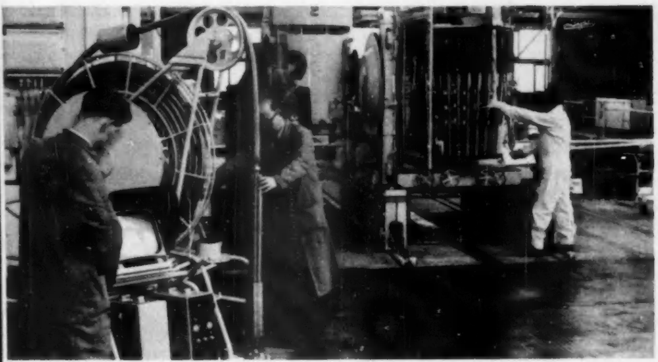


Calder Hall Nuclear Power Station, showing (*right*) Calder A completed, and (*left*) Calder B nearing completion.

The operation staff for each of the four reactors consists of a senior supervisor, a deputy supervisor, an operator, and three plant attendants, on each shift. There is in addition a staff in the steam turbo-alternator control room. The operator in charge of the reactor at any given moment has to check reactivity level, which is presented to him in terms of megawatts of equivalent heat output. He has a main thermal output meter and a drift meter. The two controls which affect reactor operation are the speed of the blowers forcing the carbon dioxide coolant through the system, and the position of the control rods which are raised and lowered in the core, to absorb more or less of the neutrons emitted during the reaction. Very slight changes in the control-rod positions (of the order of 2 or 3 mm.) are necessary from time to time to keep the drift meter within the figure of plus or minus 1½ MW of equivalent heat output. If the drift meter shows that the reactivity in the core has reached 6000 kW above normal, the reactor will automatically shut itself down.

The complex instrumentation surrounding each reactor had behaved extremely well, your correspondent was told, and he observed for himself that the actual minute-by-minute operation involved no greater degree of strain and concentration than is necessary in a conventional coal-fired station of equivalent size.

Extremely valuable data on operation problems is being accumulated daily at Calder Hall. The question of the degree of negative temperature coefficient (the relationship between reactivity and temperature of the fuel elements and the moderator) is a matter of vital concern in the design and operation of the new stations, and the burn-up, or utilisation, of given designs of fuel elements is as vital in the economic sense as the aspect previously mentioned is in the technical sense. These and many other facets of nuclear power plant operation are being intensively studied at Calder Hall, as the world's largest atomic power plant quietly goes about its business of providing a significant amount of power and a very large amount of experience.



A demonstration of the closed-circuit television camera on top of the reactor at Chapelcross. The technician in the centre is holding, in his left hand, a television camera which is transmitting, to the operator on the left, the picture. Should a mishap occur in one of the reactor tubes the camera can be lowered into it. By means of small grabs attached to the camera, small loose articles can be removed from the reactor. The man on the right is filling a basket with uranium rods for insertion into the pile.

CHAPELCROSS GOES CRITICAL

The second atomic power station in Great Britain, Chapelcross, erected near Annan, Dumfriesshire, in Scotland, was officially opened at the beginning of May 1959. It has four reactors: number one being critical and in full production of plutonium and electricity; number two being commissioned; numbers three and four will go critical in three to six months respectively. Chapelcross, apart from minor changes, follows the model of Calder Hall very closely. In fact, complete specifications of the reactor, heat exchanger, and ancillary services are now published as a matter of routine.

REACTOR

Type: Natural uranium, graphite moderated, gas cooled.
Purpose: Plutonium production.
Power production.
Capacity: 46 MW from two turbines fed by four heat exchangers.
Heat rating: 180 MW.
Complete station includes four reactors and eight turbo-alternators.
Maximum electrical output: 184 MW.
Fuel: Natural uranium.
Uranium as cast bars, 1·15 in. dia., 40 in. long.
Elements in vertical channels, six per channel.
Total number of channels: 1696.
Total investment: 130 tons.
Canning: Magnesium alloy—Magnox.
Wall-thickness of can: 0·072 in.
Extended surfaces: single-start helical fin, 0·125 in. pitch, 0·43 in. radial width, overall dia. 2·125 in.
Manufacture: cans turned from solid, swaged on to uranium, helium filled.
Moderator: Graphite.
Built up from 8 in. sq. interlocking blocks and tiles.
Drilled 4 in. (av.) holes for fuel channels.
Overall size, including reflectors: 36 ft. dia., 27 ft. high.
Supported by ball-bearings on 4 in. plates resting on diagrid.
Total weight: 1140 tons.
Core: Size 31 ft. dia., 21 ft, high.
Lattice: regular square, 8 in. pitch.
Coolant: Carbon dioxide at 100 lb./sq. in. circulating upwards through reactor.
Flow: 7·1 million lb./hour.
Ducting: 4 ft. 6 in. dia.
Inlet temperature: 140°C.
Outlet temperature: 336°C.
Shielding cooling: blown air.
Pumping: Four centrifugal blowers, one in each heat-exchanger circuit.
Total power absorbed: 5·44 MW.
Speed control=Ward-Leonard type, range 10/1.
Control: Coarse: up to 48 rods ganged together.
Fine: up to four manually operated.
Normal operation: total forty-eight rods.
Rod construction: boron steel in stainless-steel tubes.
Suspension: stainless-steel cable.
Travel: 21 ft.
Maximum rod speed for shut-off: 4 ft./sec.
Minimum automatic rod speed: 0·5 in./min.
Shielding: 6-in.-thick steel plates.
Concrete: on sides 7 ft., on top 8 ft.
Minimum density: 150 lb./cu. ft., mean: 160 lb./cu. ft.
Overall size: octagon 60 ft. across flats, 90 ft. high.
Total weight on foundations: 32,000 tons.

REACTOR PRESSURE VESSEL

General Design: Plate: 2 in. thick, ductile mild steel, "Lowtem".
Vertical cylinder: 37 ft. inside dia. and 71 ft. 6 in. high with domed ends of ellipsoidal form, the lower end having an auxiliary dome some 12 ft. dia.
Ten "A" frame supports.
Diagrid to support reactor core. Diagrid weight: 63 tons.
Manufacture: Prefabricated on site in five sections, bottom dome, two centre sections, diagrid and top dome.
Vessel sections lifted into position in reactor biological shield.
Sections welded in position.
Stress relief: 1·5 MW at 1100°F.

HEAT EXCHANGER

Type: Dual-pressure cycle.
Gas Circuit: Temperatures: 638°F and 285°F.
Steam: H.P.: 195 lb./sq. in. and L.P. 48 lb./sq. in.
77% of power generated at high pressure.
Manufacture: Each heat exchanger dispatched to site in ten sections, comprising six sections of the shell, the two domed ends and the two halves of the base. Overall size of shell: 80 ft. by 18 ft. dia. Weight: 178 tons. Total weight of H.E. with equipment: 450 tons.
Site welding of shell sections.
Stress relief: 200 kW at 360°C.
Tube sections: shot-blasted on site. Clean condition assembly.

TURBINE ALTERNATOR

Turbine: 3000 r.p.m., single-flow., 15-stage H.P. cylinder coupled in tandem to a double-flow L.P. cylinder.
Steam conditions: 185 lb./sq. in. (200 abs.) and 590°F for the H.P. unit and 38 lb./sq. in. (53 abs.) and 340°F for the L.P. unit.
Novel feature, valve "B". L.P. throttling valve to adjust L.P. steam pressure to maintain temperature of the coolant at the reactor inlet.
Alternator: 3000 r.p.m. 23 MW, at 11,000 V.

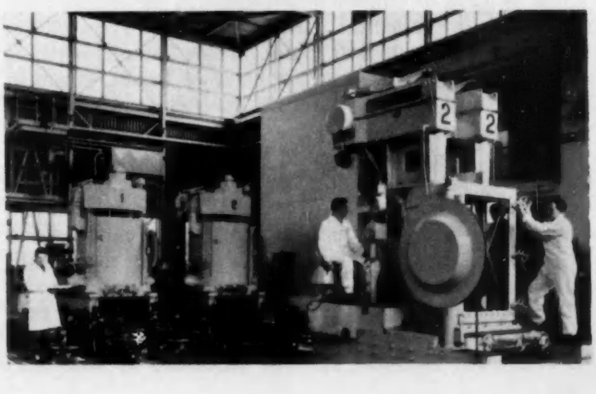
DUMP CONDENSER

Capacity: 514,600 lb./hour (=2 turbines=4 heat exchangers=1 reactor).
Desuperheaters: Primary reduces steam temperature to approximately 300°F.
Secondary reduces the temperature to saturation.

COOLING TOWER

Capacity: 3 million gal./hr. from 87°F to 70°F.
Size: 290 ft. high, throat dia. 104 ft., and ring beam dia. 200 ft.

General view of the charge floor of No. 1 reactor, showing the charge and discharge machines for loading and unloading the fuel elements.



ALEXANDER VON HUMBOLDT (1769–1859)

Friedrich Heinrich Alexander, Freiherr von Humboldt, died May 6, 1859, in his ninetieth year, after a life of many achievements. Born in Berlin on September 14, 1769, he was descended from a noble Pomeranian family. His father had served in the Seven Years' War as a major with the Prussian army and subsequently became chamberlain to the King of Prussia. Alexander received his early education from his widowed mother and later studied at the universities of Frankfurt-on-the-Oder and of Göttingen and at the Freiberg Bergakademie. Already as a student he showed that extraordinary versatility of interests which was one of his chief characteristics throughout his long life. A work on the vegetation of Freiberg (1793) was followed by an account of his experiments on muscular irritability (1797), while his association with Schiller led to the publication of a philosophical allegory, "Die Lebenskraft", in the new periodical *Die Horen.* Appointed assessor of mines at Berlin in 1792, he was soon promoted to Kgl. Preussischer Oberbergmeister of the principalities of Ansbach and Bayreuth, but after his mother's death in 1796 he felt free to satisfy his urge to travel.

Accompanied by the botanist Aimé Bonpland, he intended to join Napoleon Bonaparte in Egypt, but had to change his plan, and in 1799 they sailed for South America. While at Cumana, in Venezuela, on the night of November 12–13 Humboldt observed the meteor shower which provided the first clue to the periodicity of this phenomenon. With Bonpland he explored the course of the Orinoco and, covering 1725 miles of wild, uninhabited country in four months, found the exact position of its division from the Amazon. At Callao, in Peru, Humboldt studied the transit of Mercury and investigated the properties of guano, whose use as a fertiliser in Europe came about chiefly through his writings on the subject. On June 23, 1802, he climbed Chimborazo, in Quito—the greatest height then attained by man. The expedition, which ended in 1804, was of great value to physical geography and to meteorology and filled in many gaps in existing knowledge of Spanish America. Humboldt returned to Paris with the most extensive collection that had ever been seen in Europe. The formidable task of arranging it occupied twenty-one years and even then remained uncompleted at his death.

In his later years he was obliged to spend much time at the Prussian court and on diplomatic missions. In 1827, while inquiring into the nature of "magnetic storms" (the name he gave to abnormal deviations in the earth's magnetism), he persuaded the Russian Government to establish a chain of meteorological stations which spanned northern Asia; an appeal in 1836 to the Duke of Sussex, president of the Royal Society, brought co-operation from the British dominions.

In 1829, Humboldt, then in his sixtieth year, explored the Russian empire from the Neva to the Yenesei, covering some 9600 miles in twenty-five weeks. Though he corrected previous estimates of the height of the Central Asian plateau and discovered diamonds in the Urals, the journey was too hurried to permit any thorough investigations.

With the exception of Napoleon, Humboldt at one time was the most famous man in Europe. In his manysidedness he resembled Leibnitz. He was acclaimed as naturalist,

Specially drawn for DISCOVERY by Frank Horrabin.

traveller, pioneer in nerve physiology, founder of the science of physical geography, philosopher. Of his many contributions to knowledge the following may briefly be mentioned: his discovery of the decrease in intensity of the earth's magnetic force from the poles to the equator; his introduction of "isothermal lines", by which climatic conditions in various countries could be compared; his classification of the volcanoes of the New World into linear groups which, he suggested, corresponded with enormous underground fissures; his proof of the igneous origin of rocks, previously held to be of aqueous formation; his observation on electric eels and on the respiration of fishes and young crocodiles.

Humboldt's numerous writings include "Voyage aux régions équinoxiales du nouveau continent, fait en 1799–1804" (30 volumes); "Ansichten der Natur"; and "Kosmos", the first volume of which appeared in 1845 and the fifth volume posthumously in 1862. This encyclopaedic work emphasised the relations between forms and habits of plants and the character and soil of their habitat.

Innumerable honours were showered upon Humboldt. He was elected a foreign member of the Royal Society in 1815 and received its Copley medal in 1852. A kindly, benevolent man, given to flattery, he enjoyed good health until 1857, when he had an apoplectic stroke.

THE ANTIKYTHERA MECHANISM—AN 18TH-CENTURY ASTRONOMICAL MACHINE FROM THE 1ST CENTURY B.C.

A spectacularly complex scientific instrument from the 1st century B.C. has been the subject of recent investigations which suggest a radical re-estimation of ancient technology. The fragile and corroded remains of this instrument, a geared astronomical computer of very sophisticated design, were recovered in 1901, together with fine bronze and marble statues, from a sunken treasure ship near the tiny island of Antikythera in the south of Greece. As the earliest extensive operation in underwater archaeology it created much excitement, and this was increased in 1902 by the discovery of the fragments of an instrument amongst almost formless masses of calcification. The fragments carried Greek inscriptions of the 1st century B.C. in which astronomical words could be deciphered; they also showed the remains of many geared wheels.

The unique importance of the find was immediately recognised, and there have been several excellent published accounts which attempt to interpret the inscriptions and mechanical detail. Alas, a curtain of corrosion concealed so much crucial detail until recently that all interpretations were rather conjectural, and caution and enigma had replaced the astonishment that had first been felt. Over decades, the patient skill of the technicians in the National Museum at Athens has been applied to the delicate task of disentangling the decomposed bronze plates, gears, and divided circles of this object, agreed by all to be a precious and unique example of a hitherto unknown type of astronomical instrument.

The process of cleaning and restoration has now reached a point where the curtain is down and a considerable portion of the device can be reconstructed with some certainty. Last summer the fragments were subjected to a minute examination by Dr J. Price, an expert on the history of science, formerly of Cambridge University, now of the Institute for Advanced Study, Princeton, U.S.A. Working with archaeologists and epigraphers, he has now been able to show that the mechanism was designed to calculate the dates and times of astronomical events and exhibit this information by means of three multiple dials. The events concern such things as the heliacal risings and settings of stars, the lunar phases, eclipses, and planetary stations and retrogradations, and these were taken care of by cycles of various periods, built into the gearing, rather than by geometrical modelling, as in a planetarium.

The astronomical significance of the mechanism reflects only the very high level of Greek astronomy that has long been appreciated. What, however, is most remarkable about the device is its delicate sophistication as a piece of fine machinery. With its multiple gear trains and epicyclic gearing it is at least one order of magnitude more complicated than anything known from such classical scientific texts as those of Hero, Vitruvius, or Ptolemy. Dr Price suggests that scientific technology did not again reach this high level until quite recent times. It seems, however, he reports, that a tradition of such instruments was passed from the Greeks to the Arabs, who built similar devices and in turn handed on the tradition to Europe, where it resulted in the medieval mechanical clock and in the whole range of more varied scientific instruments that branch out on this evolutionary tree.

The current (June) number of *Scientific American* contains a detailed article by Dr Price, describing his reconstruction of the mechanism and giving photographs and diagrams of the fragments in Athens.

NEW RECRUITS FOR NORWEGIAN RESEARCH

According to the Managing Director of the Norwegian Council for Scientific and Industrial Research, between 0·6 and 0·7% of the gross national product of Norway is invested in scientific research. The Council employs 700 people at its headquarters and its associated institutes, and has a current budget of 28 million kroner (£1·4 million).

The CSIR was established by a Parliamentary Act in 1946. It has twenty-five members representing in near equal proportions the Government, industry, and the nation's research institutes. It is an independent organisation dedicated to promote scientific and industrial research, and to ensure that the results are used for the advancement of industrial life. One of the first tasks undertaken by the Council was to increase the number of recruits for Norway's research institutes by awarding Travel Fellowships to university graduates seeking advanced training abroad. Altogether 320 such fellowships have been awarded to 244 candidates. Secondly, it has financed a growing number of research projects at Norwegian universities. Possibly the Council's most notable achievement has been the establishment of new research institutes, the first being the Atomic Energy Institute. The main projects of this institute at present are the study of plans for an atomic propulsion tanker and the construction of a zero-energy reactor.

BLOOD-GROUPS AND ANTHROPOLOGY

The key to physical anthropology is now realised to be genetics. Advances in human genetics have been made along two lines. The study of congenital diseases is mostly concerned with sporadic harmful mutations, which can make little contribution to anthropology. Nevertheless, even congenital disorders can be so frequent and so differentially distributed that they can serve as markers in the classification of the human race. This applies particularly to the haemoglobin diseases like sickle-cell anaemia and thalassaemia, and also to the rarer conditions of colour blindness and anencephaly. However, the most useful characters are those which are normal and for which most populations are polymorphic. The genetics of form and colour of the human body have not yet been properly defined.

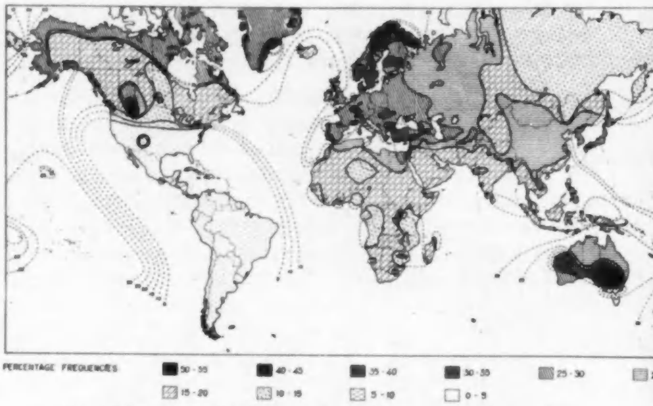
For a long time almost the only simple characters known in this class were the blood-groups, of which the ABO system was first discovered, then the MN and P blood-groups, later on the Rhesus blood-group system and numerous others such as the Lewis blood-groups, Lutheran, Kell, Duffy, Kidd, and other systems. It was also found that the ability to taste phenylthiocarbamide was inherited as a Mendelian character, the secretor state for the blood-group substances A and B, and for the H substance

found in connexion with blood-group O. There are now known a number of enzyme deficiencies which are inherited, though only the common ones like that of glucose-6-dehydrogenase associated with easily induced haemolysis, give rise to true polymorphism. Gradually the complexity of the plasma proteins is recognised as being controlled by simple genetic systems.

Shortly after the discovery of the ABO blood-group system the observation was made in Salonika, where soldiers from many countries were stationed, that the different nations and races showed a different frequency of these genes. Since then, enormous strides have been made. The B group is most frequent in India and in Central Africa, and the farther people live from these foci the lower will be the B frequency.

For the MN system a great difference can be found between men living east and west of a line running from north to south between South-east Asia and Australasia. Those west of it show a higher frequency of N than of M, whereas elsewhere M is predominant. The various Rhesus gene combinations afford even more subtle differences, of which the most important is probably the finding of a high Rhesus $-R_o$ frequency in all the people of Negroid Africa.

All these characters can be considered in two ways from the anthropological point of view. They may be seen as pure anthropological markers, stable from one generation to the next, or they may be considered as the outcome of natural selection changing from environment to environment and from generation to generation. Even a stable polymorphism could not have arisen without mutations and almost certainly natural selection, and perhaps some genetic drift. Stable polymorphism is likely to be balanced polymorphism, where two or more allelic characters have all different advantages and disadvantages. Such a balanced polymorphism exists for sickling, where the homozygous

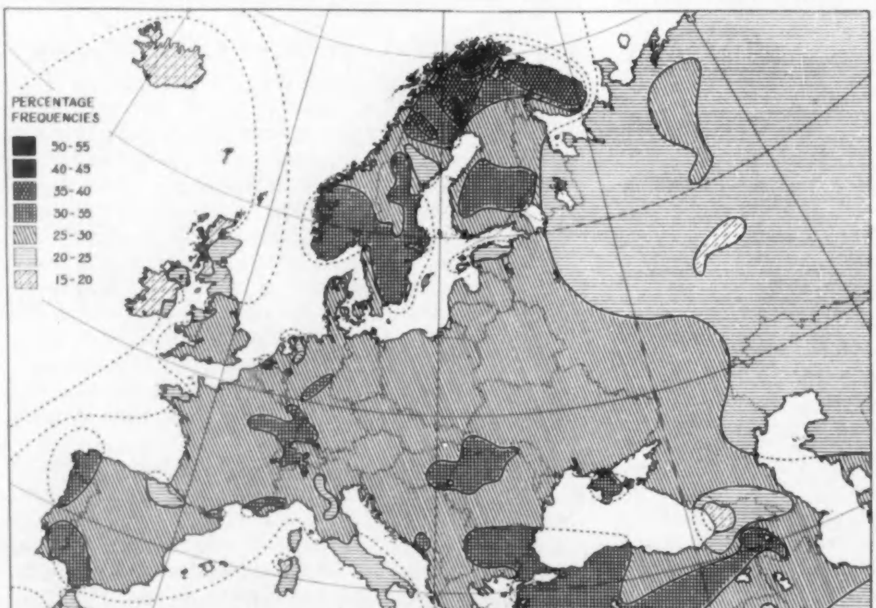


Distribution of blood-group gene A in the Aboriginal populations of the world.

(Photographs reproduced from "The ABO Blood-Groups" by A. E. Mourant, Ada C. Kopeć, Kazimiera Domaniewska-Sobczak, Blackwell Scientific Publications, 1958)

sicklers suffer from sickle-cell anaemia and the non-sicklers are more likely to die from malaria in early infancy, but where the sickle-cell heterozygotes both, have no sickle-cell anaemia and are relatively protected against malaria.

The blood-groups were once thought to be "neutral" as regards selection, but the work of Aird, Fraser Roberts, Clarke, McConnell, and others, on blood-groups and disease has shown that certain blood-groups almost certainly have a selective advantage over others. Thus blood-group A turns up significantly more often in patients with cancer of the stomach than in a comparable series of controls. Even more striking is the relatively high frequency of blood-group O in patients with duodenal ulcer. However, this work has so far been only concerned with the ABO blood-groups and with the secretor system, in both of



Distribution of blood-group gene A in Europe.

which homozygotes are indistinguishable by any direct test from certain heterozygotes. A person with blood-group A may either be homozygous for the A gene (AA) or heterozygous for the genes responsible for A and O (AO). A true balanced polymorphism would imply that Nature is making a distinction which cannot be made in the laboratory.

In 1954 Dr A. E. Mourant, the Director of the Medical Research Council Blood Group Reference Laboratory, published his already classical book on "The Distribution of the Human Blood Groups". He already stressed then that for practical purposes two classes of characters could be distinguished—haemoglobins, the secretor factors, and probably the ABO groups, and perhaps others, which are subject to relatively rapid natural selection and can be used for tracing relatively recent anthropological events, and stable systems like the MN groups and surprisingly the Rhesus blood-groups to be used for long distant anthropological history. Thus even within Britain the ABO frequencies vary significantly and the higher incidence of blood-group A in the east of the British Isles can be related to the admixture of Viking invaders. On the other hand, no population has yet been found in Africa south of the Sahara, amongst which the elsewhere rare Rhesus blood-group R_0 was not present in more than 50%. Despite the completeness of the work published in 1954, the author could not then fully cope with the accumulating mass of ABO data—though much was offered to the reader in the text in an extensive bibliography and fascinating maps of their world distribution.

Now, with the help of Ada Kopeć and Kazimiera Domaniewska-Sobczak, Dr A. E. Mourant has produced exhaustive tables of all known ABO data and up-to-date maps of their distribution. The book surveys the outcome of just under 6 million blood-group estimations! It is unlikely that this stupendous task will ever be repeated in entirety, though we may look forward to future reprints with added supplements. The book is the work of an encyclopaedic scholar of a type rarely found in the 20th century. Dr Mourant is not only an expert in the field of blood-groups, as might be expected from his position as Director of the Blood Group Reference Laboratory—and indeed a number of groups have been discovered by him—he is also a geneticist who has made lasting contributions to our understanding of their inheritance, and he has been involved in the last fifteen years in nearly all major advances in the anthropological field where blood-groups were concerned. Mourant is the honorary adviser, Kopeć the statistician, and Domaniewska-Sobczak the librarian of the Nuffield Blood Group Centre, yet another institution for which we must be grateful to the Nuffield Foundation's foresight.

This Centre is now engaged in producing a very complete British survey, and the mere keeping up to date of the two books published so far should be a heavy task. Unless there are such institutions prepared to cope with the increasingly rapid accumulation of data on swelling numbers of genetical systems these would largely be lost to human anthropology and human genetics. The importance of such institutions and their success lies in the co-ordination of scientific knowledge—one of the great current problems of the world of learning.

LIQUID METHANE TRANSPORTATION

Mankind needs energy to enable it to live, and for the past few hundred years it has been using the stored-up geological resources of fuel as its source of energy. During the last few decades it is petroleum that has been drawn from its underground reserves in ever increasing quantities, as men have become more and more dependent on it. The extraction of liquid oil has been accompanied by an appalling waste of the gaseous hydrocarbons associated with it, for in many cases the oilfields are remote from any industrial communities which could make use of the gas. In the Middle East alone it has been estimated that 300,000 million cu. ft. of hydrocarbon gases are burnt annually at flare-stacks; and this would be enough to provide the whole of Great Britain with gas if only it could be transported here.

An experiment which the Gas Council—in association with the American company, Constock International Methane Ltd—is now conducting will probably make it possible for considerable quantities of the gas now wasted to be brought to England as a liquid in special tankers. It was pointed out (DISCOVERY, 1956, vol. 17, No. 9, p. 360) that very special problems attend the transportation of bulk liquid at −160°C. Many ordinary constructional materials have quite different physical properties at this temperature, and it is probable that the disastrous fire at Cleveland, U.S.A., in 1941, when a liquid methane tank collapsed and spilled its contents into the neighbouring township, was due to this fact.

Since that time careful studies have been made on the effects of low temperatures on physical properties, and there is now no particular hazard to be anticipated with liquid methane storage. The original proposal to use it as a means of storing gas in the summer for use in winter has not been followed up in the U.S.A. largely because of the success of underground storage (see DISCOVERY, 1959, vol. 20, No. 4, p. 142), which is cheaper. For the conveyance of gas from, say, Venezuela to Britain, however, liquefaction should be a most valuable process. Although liquid methane has a very low density (0·42), it occupies only one six-hundredth of the volume of the gas, and it can be conveyed at atmospheric pressure with a "boil-off" loss of only about 0·3% per day. The evaporation of this quantity serves to keep the rest of the liquid cold.

The exact arrangement of the tanks aboard the *Methane Pioneer* has not been disclosed, but the voyage which took place in February conveyed 2000 tons of liquefied methane from the Gulf Coast of U.S.A. to the specially constructed dock and storage tanks at Canvey Island. From these tanks the gas is evaporated and flows into pipes connecting the wharf with Romford gasworks. At Romford a catalytic cracking plant has been set up, which causes the methane to react with steam to produce hydrogen and carbon monoxide. When this mixture is reinforced with about 20% of methane which has by-passed the cracker, the final mixture closely resembles ordinary town gas.

If a continuous and reliable supply of methane could be assured, it might be possible ultimately to eliminate this cracking process and distribute the gas without modification. The calorific value is about 2½ times ordinary town gas, however, so modifications would be required to all gas-burning appliances before the change-over could be made.

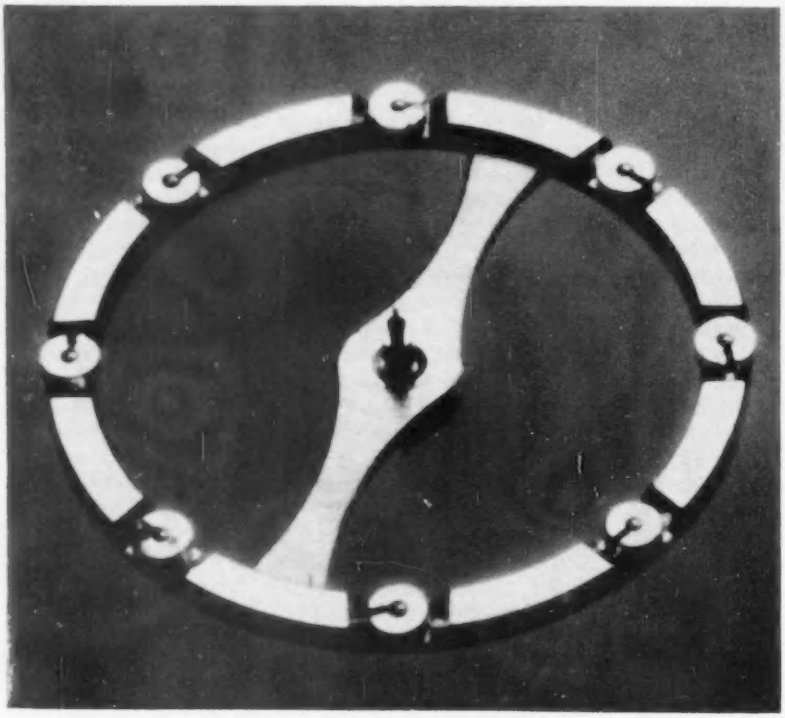


FIG. 1. The Gyromax Balance-wheel.

HOROLOGY: PAST, TRANSITIONAL AND FUTURE

ANDRÉ G. KRASSOÏEVITCH

Head of Research and Development, Patek Philippe Geneva, Switzerland

Watches activated by solar and nuclear energy have been devised as a result of contemporary work on the improvement of watches, for such work has been chiefly concerned with modifying the source of energy. It is anticipated that future research will concentrate more on the moving parts, perhaps to produce the "static" watch.

The idea of time is as old as man. This idea has grown in importance through the years, becoming more precisely defined until it gradually pervaded the whole of man's existence. Living originally in close communion with nature, whose recurring phenomena soon grew familiar to him, man first became an astronomer, then a navigator and a mathematician; later on, he became an engineer and a physicist. And always, following him everywhere throughout this long evolution, the idea of time became more concrete, gradually penetrating his daily life, his work as well as his leisure. It became possible to *measure* time with more and more accuracy; for the physicist it became a fundamental quantity, for the philosopher a subject of constant meditation. So, in the course of this evolution through the centuries, the clepsydra* and the sand-glass of our distant forebears have been transformed into the molecular and atomic clocks of today. So, too, the accuracy of time measurement has been greatly improved. The first known instruments probably lost about one hour in a day. The most highly developed devices of today are so incredibly accurate that they lose only one second in three hundred years.

A complete panorama of the history of time measurement throughout the centuries would be beyond the scope of this article. A few of the most significant examples will be given, examples concerning devices of small dimensions, and therefore portable, and chosen mainly from work carried out by one of the Swiss watch manufacturers.

In order to present a clearer picture, time-keeping devices will be divided arbitrarily into three broad categories: traditional horology, transitional (or intermediate) horology, and, lastly, horology of the future.

The first category includes all those movements where the energy required to drive the oscillating system which keeps the time is stored in elastic form (mainspring), or in a gravity field, and whose oscillator, which is completely mechanical, is either a balance and spring or a pendulum.

The second category bridges, as it were, the gap between the first and the third, and is distinguished by either a change in the source of energy (light, chemical energy, nuclear energy) or in the oscillator (which has become electro-mechanical) or both.

Lastly, in the third category, not only has the source of energy changed but, more especially, the oscillator has now become completely electronic: there are no more moving parts for time-keeping. In addition, the mechanisms for counting the oscillations and indicating the time, which were mechanical in the first two categories, are now electronic also. There is no longer any moving part: the watch has become "static".

TRADITIONAL HOROLOGY

Before describing briefly some of the recent improvements in this first category of time-keeping instruments, we should like to recall the way in which the best modern chronometers are compared during official tests in specialised observatories. These tests, known as observatory

* While writing this article the author received Mr F. A. B. Ward's short work, "Time Measurement", published by the Science Museum, and representing the first (historical) part of a larger work. It gives a description, often very detailed, of the instruments used in the measurement of time, from the clepsydra of the ancients to the most recent atomic clock. In addition, it recalls astronomical conceptions and the general principles governing time measurement. Finally, two chapters are devoted to chronographs, alarm mechanisms, time recorders, and switches. This well documented booklet is recommended to all those who, professionally or non-professionally, are interested in the measurement of time.

competitions, are to the watch-making industry what racing is to the motor industry; in other words, they are extremely stringent tests. The best-known observatories specialising in this kind of work are, in Switzerland, those of Geneva (since 1871) and Neuchâtel; in France, the Besançon Observatory; in Germany, the Hamburg Observatory; in the United States, the Washington Observatory; and in England, the National Physical Laboratory at Teddington (which, unfortunately, has published no results for some years). The chronometers are divided into categories so that they can be compared more easily with each other. Thus, in the Geneva Observatory (which has international tests, so that any manufacturer can compete) there are five categories: marine chronometers, board chronometers, large and small pocket chronometers and wrist chronometers, the distinction between these different types of time-keeping instruments being essentially one of diameter. In the course of rigorous tests, lasting forty-four or sixty-four days, the performance of chronometers is compared with the highly accurate time standards of the Observatory quartz crystal clocks by placing each chronometer in different positions (five in all), and at various temperatures (4°, 20°, and 36°C). The average variation in rate is always measured over a period of twenty-four hours and never exceeds more than a few tenths of a second per day. The results of these different tests are averaged to give the "classification number" of the chronometer. Thus, a perfect specimen with no detectable variation would score sixty points.

Now a study of the main advances in traditional watch-making during recent years shows that all the parts have been greatly improved: the springs are now unbreakable and will last almost indefinitely; with new methods of manufacture the gear-wheels have become more accurate, and their mass production with the same degree of precision is now possible (units of length in horology are one-hundredth and one-thousandth of a millimetre); the escapement, the lubrication, and the oscillator have also undergone many improvements.

Thus, the introduction of the Gyromax balance (see Fig. 1) has resulted in the following advantages over the conventional balance-wheel:

1. Adjustments (correction of the period of oscillation) become very fine and are easily made, since they are carried out by means of the small, slotted collets seen in the photograph, and no longer by the well known rougher and less accurate method, which consists of modifying the effective length of the hair-spring with the regulator. The orientation of the slit around the axis very slightly alters the moment of inertia of the balance-wheel, and thus its period of oscillation. In addition, proper adjustment is now easily restored after dismantling. These conditions are, of course, desirable for the easy adjustment of a precision watch, which thus no longer requires a regulator.
2. The advent of the auto-compensating hair-spring permits a monometallic balance. It has thus become possible to dispense with the screws for temperature compensation and at the same time, because of the Gyromax, to increase the circumference of the rim and consequently the total moment of inertia (without adding to the weight); this is essential for obtaining increased control power from the balance.
3. The more favourable aerodynamic conditions of the Gyromax lessens the influence of the barometric pressure, which normally changes from thirteen-thousandths of a second per day and per millimetre of mercury to eleven-thousandths of a second per day and per millimetre of mercury.

The self-winding watch represents another important advance. The energy provided by moving the arm in the field of the earth's gravity is stored in a mainspring by means of a heavy rotor which turns very freely on its axis. Hand-winding is thus no longer necessary, and the amount of spring tension being more or less constant the accuracy of such a watch is very high, ranging about one second per day.

Everyone is aware of the high sensitivity of watches to magnetic fields: it was therefore necessary to find some

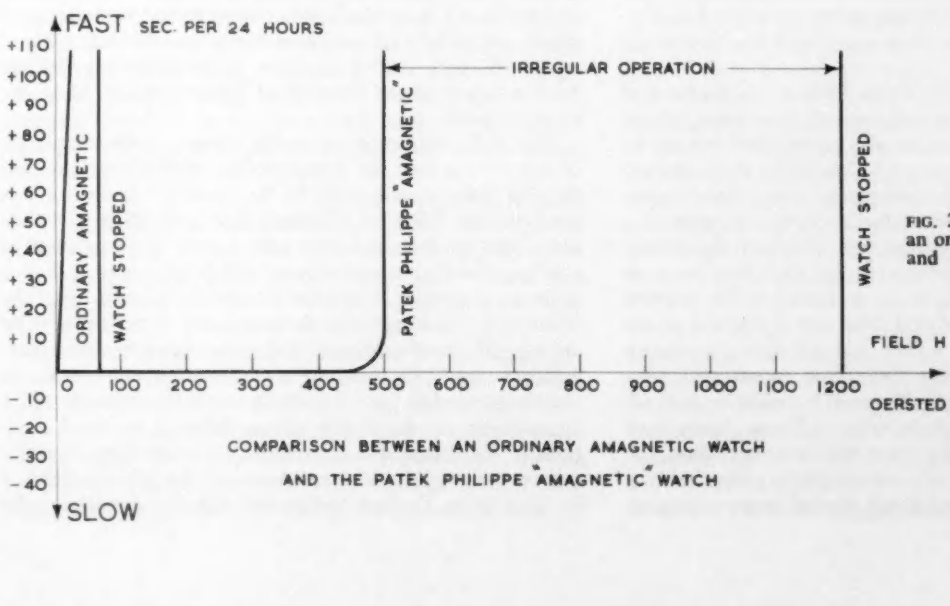


FIG. 2. Comparison between an ordinary amagnetic watch and the Patek Philippe amagnetic watch.

effective means of protection which would enable people wearing watches to move about freely in the proximity of domestic or laboratory electrical appliances without fear of damaging the watch. In the amagnetic model by Patek Philippe, this protection has been provided by means of a screen of high permeability material, which completely encases the movement and at the same time by substituting some important non-ferro-magnetic parts for the traditional ferro-magnetic. Thus the protection is both internal and external.

Placed in fields of up to 450 gauss the watch undergoes no variation. After passing through a field of between 450 and 1200 gauss, the variations are a few seconds per day; if kept in a field of 1200 gauss, the watch stops (see Fig. 2). Finally, if it is removed after stoppage, it gains 30 seconds per day, but it is very easy to demagnetise by the usual procedure of placing it in an alternating magnetic field.

An improved model, with a double screen, was worn by one of the physicists of CERN (European Centre for Nuclear Research) at Geneva, and after going through extremely high fields (up to 15,000 gauss), no noticeable variation of rate was detected. The extent of such protection may be fully realised when it is pointed out that in the proximity of electrical appliances in general use, the magnetic fields seldom exceed 100 gauss. As regards the thickness of watches protected in this way, it is scarcely more than that of ordinary, unprotected models.

TRANSITIONAL HOROLOGY

In this category, as stated above, a great deal of research has been carried out, and some of this has led to interesting results. Before examining some of these results, however, the following must be made clear: if a time-keeping instrument in this category is to have a really great future it must show certain advantages over the traditional timepiece, either in its source of energy (less frequent winding) or its oscillator (greater precision), or else in its strength and simplicity. But the traditional watch, in its present stage of development, has reached such a degree of perfection that it is plainly difficult to improve on it simply by introducing an electro-mechanical oscillating system. That is why much work, especially regarding precision watches, has been concerned only with modifying the source of energy.

Thus, as long ago as 1950, Patek Philippe began the first experiments with a view to using energy from light, which has resulted in the construction of a small clock wound by light. The principle of this is the following: a photo-electric cell charges an accumulator supplying power to a highly sensitive micromotor, which actuates the mainspring of a traditional time-keeping mechanism. There is no circuit-breaker between the cell and the accumulator, only between the motor and the accumulator, to stop the winding process when the spring is fully wound. The average power of the whole of this system is 7 μW, and its accuracy ranges up to one second per day. Such low power and high accuracy in the present state of research would be difficult to obtain with an electro-mechanical oscillator. Apart from the very short periods when the motor is in operation, the cell continually charges the accumulator. One of the characteristics of the latter is that it cannot be over-charged.

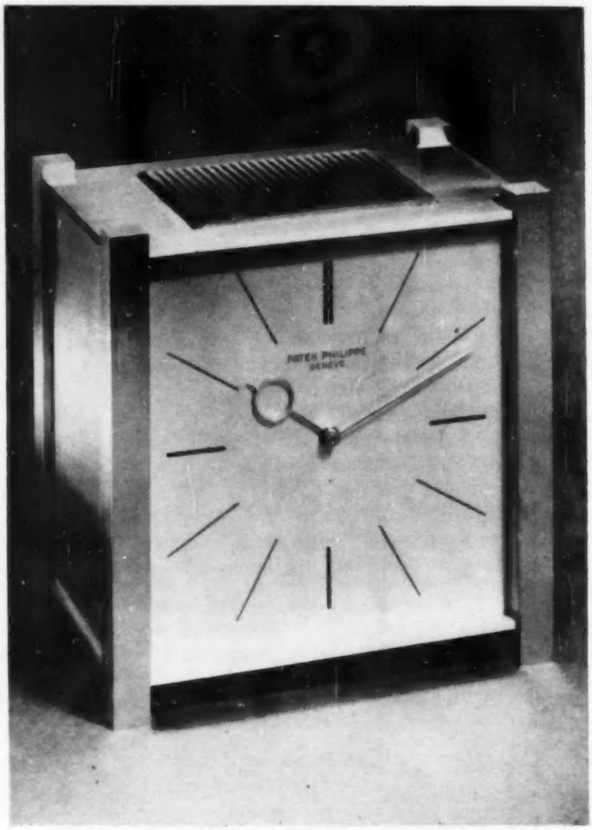


FIG. 3. A small clock which uses the energy of light to wind the mainspring of a traditional time-keeping mechanism.

Another is that it represents a year's supply of power should the source of light be withdrawn. Finally, the threshold of energy collection is very low, since charging starts with an illumination of 50 lux. Fig. 3 shows a recent model of this small clock with its photo-electric cell.

The study and manufacture of this type of clock have, moreover, led to a whole series of very interesting experiments in the field of miniature electro-mechanical devices. As we shall see farther on, these present great possibilities for the future of the horological industry, where it is able to adapt itself.

The D.C. micromotor (see Fig. 4) is a perfect example of this. It was first developed for the small light clock, but has, in fact, shown itself to be capable of many other applications. With an efficiency figure of 85%, it is the ideal element for use where only a very small amount of energy is available and where voltage does not exceed a fraction of a volt. Its sphere is that of the milli- and the microwatt. For integrating, for measuring, for computing by analogy (it transforms electrical quantities into mechanical quantities and vice versa), it is particularly well adapted to electronic circuits and especially to transistor apparatus. In addition, its small dimensions make it an ideal component for miniature equipment, and its low starting-current (about 20 μA) suggests its use for tele-control and in the guiding devices of missiles. Finally, it works under

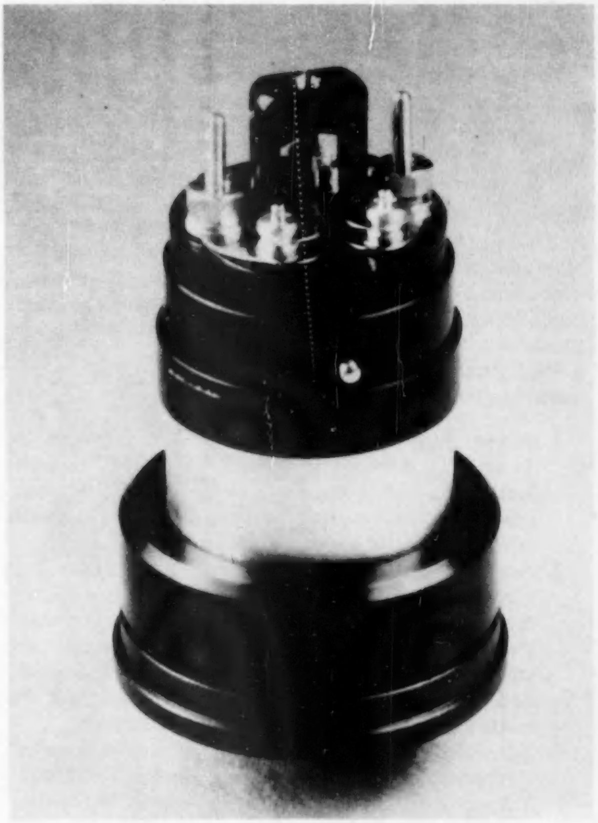


FIG. 4. A D.C. micromotor with dust protection removed.

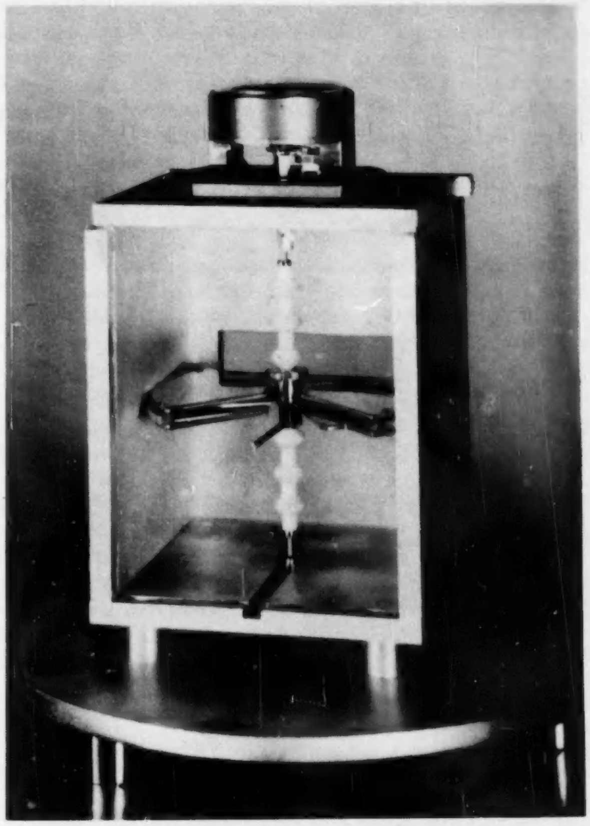


FIG. 5. Prototype motor driven by nuclear energy showing the tube containing strontium-90, the motor shaft of non-conductive material, and the fixed and movable electrodes. On top of the case the standard clock mechanism can be seen. (The front shielding was removed to take the photograph of the interior of the motor.)

vacuum, in contrast to the majority of D.C. motors. It is easy to understand that in order to achieve such a result especial care had to be devoted to engineering and to minimising friction losses.

The use of energy from light, its storage in the form of electricity, and also the most useful means of applying it to a very low-powered mechanism have provided the modern solution of intermittent winding, with maximum efficiency. The research required to arrive at this result allowed some interesting experiments concerning very low-powered electrical circuits: micro-accumulators chargeable by light but not over-chargeable, adapted photo-voltaic cells, micro-switches, and so forth.

The search for possible sources of energy for a traditional time-keeping mechanism inevitably encompasses nuclear energy. When more and more nuclear reactors began to appear all over the world it became evident that cheap sources of radioactive material would soon be available. From then it became natural therefore to see how these sources could be used as a means of providing energy, especially in horology, where the working energy required is in the region of a few microwatts and where dimensions are very small. If the discussion is limited to sources which emit charged particles, two types of generators can be described: one which transforms nuclear energy into mechanical energy direct (working at high voltage) and one which makes use of the junction of semiconductors (working at low voltage).

THE NUCLEAR MOTOR

Fig. 5 shows one of the latest prototypes of nuclear motor made by Patek Philippe, and belonging to the first category. Its principle is straightforward: charge of a capacitor by beta rays emitted from a source of Sr^{90}–Y^{90} (half-life period about twenty-five years), followed by the appearance of electrostatic forces between the stator and the rotor, pulling of the rotor, discharge of the capacitor at the end of this pull and renewal of the cycle. The torque is transmitted by the rotor to a wheel near the oscillator by means of a small energy-storing spring, and obviously the whole device must work under vacuum.

The energy provided by this device from a source of 50 mc. of Sr^{90}–Y^{90} is about 2 to 3 μW, its working voltage about 10 kV and its period about 13 minutes. Difficulties encountered are due to various factors: insulation in the presence of intense beta bombardment; the surface state and the composition of the electrodes (subjected both to radiation and to a field ranging about 200 to 300 kV/cm.); the deposition of radioactive material by means of a special technique on a thin-walled microtube; and finally, all the

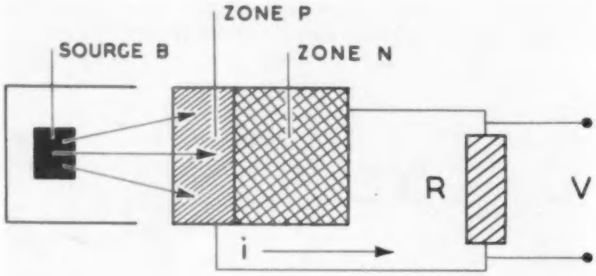


FIG. 6. Diagram of the arrangements when a beta-ray source is used to provide a current.

problems of optimum geometry, engineering and shielding. Having overcome all these difficulties, apart from some secondary effects caused by a cold-discharge mechanism forming in the space between the electrodes, problems of manufacture can now be considered: the laboratory-maintained vacuum may now be replaced by a sealed vacuum through the use of a kind of radio valve containing the motor, and the clock mechanism can be coupled magnetically through the glass. However, although fairly extensive research has been carried out on the prototype, the presence of a certain amount of risk, and an industrial future less brilliant than was at first supposed, have led Patek Philippe to reconsider its research programme and turn it in a much more promising direction, to which there is further reference below.

The other type of nuclear generator, with low voltage, uses the junctions of semiconductors irradiated from a beta-ray source (see Fig. 6). The beta emitters considered up to now have been the Sr^{90}–Y^{90}, the Ni^{63} and the Pm^{147}. These generators have the advantage of providing a more intense current than the preceding ones (multiplication factor ranging about $2 \cdot 10^5$), though their voltages are only a few hundredths of a millivolt in open-circuit conditions. They are therefore better adapted to supply miniature electric and electronic circuits, and a vacuum is no longer necessary. However, two major drawbacks still prevent their application: first, the deterioration of the crystalline structure of the semiconductor after a certain amount of exposure to radiation, and secondly, the very low power obtained from the radioactive isotope, even for quite large quantities (amounting to several curies), when the use of electronic circuits with transistors is considered. Problems of protection and cost are also raised here, and it would be better to wait a little longer before deciding whether the radioactive pile may with advantage replace the battery or chemical accumulator of today.

We still have to study the different systems of small electro-mechanical oscillators, which for some years have been the subject of much specialised research. Since it concerns oscillators, they must obviously have a non-linear element: either a mechanical contact or a transistor. The oscillating system is always mechanical, but is kept in motion electrically. Fig. 7 gives a diagrammatic picture of the two possibilities: on the left, the device with contact and driving coil (the oscillator is represented by a magnetic bar N–S and a hair-spring), and on the right, the device with transistor amplifier (A), control coil (B_1) and driving coil (B_2). These roles may be reversed by having a moving coil and static magnets. But then a moving contact is required, as in the Hamilton electric watch which recently appeared on the market.

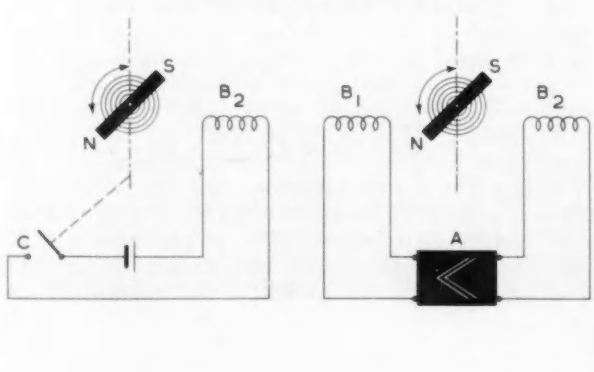
The astonishing progress in the field of miniaturisation which has taken place in the last few years has led to a reduction in the dimension of batteries or chemical accumulators, magnets, and coils, and it is now possible to accommodate these in the small volume of a watch without much difficulty. The cobalt-platinum alloy for permanent magnets and the mercury oxide battery are two of the most characteristic examples. But this is not enough. It is still necessary to assemble these elements to establish a standard time-keeping instrument with an accuracy of 10^{-5}, whose sturdiness, reliability, and life compare favourably with a traditional automatic watch. Investigations to date in numerous laboratories have shown that:

1. Microcontact devices give the best results with regard to accuracy (which approximates to that of ordinary watches) and consumption. Unfortunately, the reliability of a microcontact element becomes uncertain after working for some time.
2. An alternative to the microcontact is the transistor: then the accuracy of the oscillator becomes unsatisfactory and consumption is much higher. The sensitivity of the transistor to surrounding temperature changes complicates matters still further, and in the end the advantage of finding a substitute for the contact is not worth the disadvantage it entails.
3. For the moment, the main interest of some electro-mechanical oscillating systems lies in a greater simplification of the whole of the time-keeping mechanism, and it is only here that they show favourable comparison with present-day traditional watches.

An interesting American development is the miniature tuning-fork watch, prototypes of which are at present undergoing reliability tests. It consists of an oscillator stabilised by a tuning-fork with a transistor, probably working at some tens of cycles per second (the exact figure is not yet known). The frequency division and the counting are mechanical, and the accuracy appears to be greater than that of an ordinary watch. However, it is perhaps better to reserve judgment until the official results are made known.

As a final comment on transitional horology, it must be admitted that a satisfactory electro-mechanical descendant of the traditional controlling system has not yet been found. But many people believe that the true future of time-

FIG. 7. Two possible ways of using electro-mechanical oscillators for clockwork mechanisms.



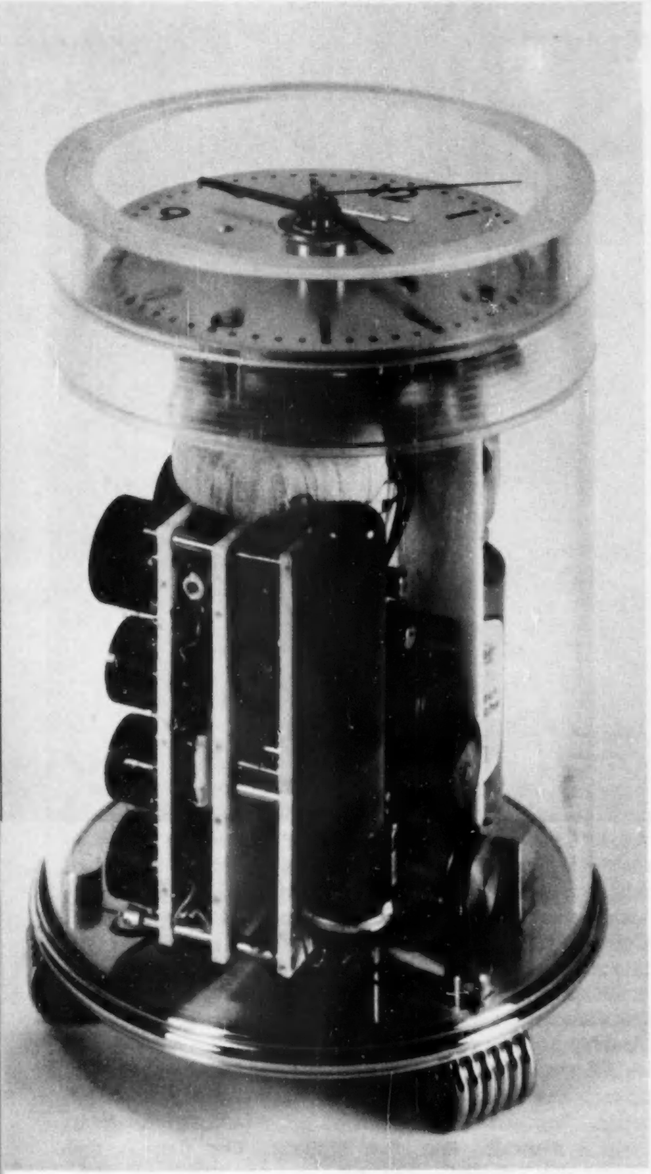


FIG. 8. Prototype of a miniature quartz clock.

keeping mechanisms does not lie in this field, and that the research and development carried out up to now only represent one more stage in the journey towards horology of tomorrow.

HOROLOGY OF THE FUTURE

This final category, which, in the author's view, represents the real future of time-keeping mechanisms, includes, as mentioned earlier, oscillators without moving parts, and more precisely miniature electronic oscillators. In addition, mechanisms for counting and indicating time also tend to be replaced by electronic systems: the watch is becoming "static". Another essential point is that the quality of the resonant circuit, denoted by Q, must be high so that its associated accuracy may also be high. This is also one of the major difficulties which confront laboratories dealing with this problem. In fact, with an ordinary oscillating circuit, L–C for example, it is not possible to attain an accuracy value equal or superior to that of the best modern watches. It is therefore necessary to add a stabilising element to control the frequency. Numerous research institutes are at present searching for such an element, which must also be of very small dimensions.

However, one of these elements is already well known: it is quartz, whose application, as an accuracy standard in observatories, has become more and more extensive during the last thirty years. Although, for the present, its dimensions prevent its use in an electronic wrist-watch, the author wishes to show that it is quite possible to produce a miniature quartz clock of great precision, and no larger than an ordinary small clock. Fig. 8 shows one of the first prototypes made by Patek Philippe, which may be described briefly.

The essential element is a quartz oscillator with a frequency of 10,000 c/s, which is then divided electronically until it is only a few cycles per second. This low frequency supplies a synchronous micromotor, which turns the hands by means of a reducing gear-train. The precision of this instrument is that of quartz, which in this prototype is 10^{-6} (that is to say, one-tenth of a second per day) in a temperature range of 0°C to 50°C. The whole system, apart from the time-indicating mechanism, is entirely electronic. In future models, however, the substitution of this mechanism by an electronic device is contemplated, and *the hands will then no longer be necessary*.

Another improvement on the ordinary quartz clock is that its total power is in a range of about 15 mW only. This permits a completely independent supply, by means of solar batteries. The numerous applications of this instrument will not be listed here but the advantages of its use may be plainly seen, either as a marine or aviation chronometer, or in general wherever frequency and time standards of great precision are required.

Clearly, the progress already made is small compared with what still remains to be done to attain the dimensions of a wrist-watch. However, the ideal solution as regards the latter may be found in what may be called the receiver watch. It would also be electronic, would be capable of receiving high-precision signals (controlled by molecular or atomic standards) and would always be very accurate, being synchronised by the transmitter. In another still more interesting variation, this watch might contain a local oscillator, periodically synchronised by a pilot-transmitter, and of adequate precision for a short length of time. Though many problems, relating mainly to information theory, still have to be solved before reaching this result, the most difficult of all will certainly be those at government level: location of transmitters, allocation of frequencies, and so forth. However, there is no doubt that this field offers some of the greatest possibilities for the future of horology.

In conclusion, although there is still much to say about each category, it is hoped that the examples mentioned have succeeded in giving a general outline of the present state of horology, and also of some personal views, based on experience, of what the author believes to be its future.

TAMING THE ST LAWRENCE

VILMA SCOTT

Together, Canada and the United States have built the second largest power dam in the world. The St Lawrence River Power Project was completed in only five years, but its construction was delayed by more than one hundred years of government dispute.*

FIG. 1. On July 1, 1958, a 600-ft.-long cofferdam was breached by 30 tons of explosives, releasing water into the headpond area of the St Lawrence Power Project. The cofferdam was one of two built to de-water the power-houses site.

(By courtesy of Ontario Hydro)

Long Sault, Soulanges, Lachine—these rapids in the St Lawrence River had hindered the passage of ships between the Atlantic Ocean and the Great Lakes for more than three hundred years. With the era of canal-building in the 19th century, small ships were enabled to by-pass the rapids, but larger ocean-going vessels were still barred. In 1825 Canada conceived the ambition of building a St Lawrence Seaway, and gradually the plans were extended to include the harnessing of the river's latent power.

Early in 1957 the roar of the Long Sault Rapids was silenced. The rocky river-bed lay exposed for the first time in history. The waters of the Long Sault had been cut off by the construction of two large cofferdams as the first major step in the St Lawrence Power Project. Contractors for the Hydro-Electric Power Commission of Ontario (Ontario Hydro) and the Power Authority of the State of New York, started work in August 1954. By midsummer 1955 the excavations for the American power-house and one of the dams were well under way, and excavations for the main dam finished. By early 1956 most of the preparation of the work sites was completed and substantial progress made on building the permanent structures. At the end of 1957 the permanent structures were well advanced and the installation of the turbines, generators, and other equipment at the power-house site was begun; by this time nearly all the dykes on both sides of the river had been completed. The headpond area was flooded, as scheduled, on July 1, 1958, thus creating a new lake of about 100 sq. miles, and providing power for the first time. The official opening occurred two months later. The power project was originally scheduled for completion some time in 1960, but will be finished this month.

* A complete account of the St Lawrence project has just been published by Methuen, "The St Lawrence Seaway", 157 pp., 12*s.* 6*d.*

INTERNATIONAL PROBLEM

The smaller the margin between the two extremes of flow, the more reliable a river is for year-round power production. With a minimum flow one-half its maximum, the St Lawrence is one of the most dependable rivers in the world. By comparison, the Ottawa River has a minimum flow one-twelfth the maximum, while the Columbia River, with the world's largest hydro-electric development (Grand Coulee), has a minimum flow of one-thirty-third its maximum.

From Lake Ontario to a point just outside Cornwall, Canada, the St Lawrence forms the boundary between New York State and the Province of Ontario; from Cornwall to the Atlantic it is entirely in Canadian territory. Let us take a look at the river as it was before construction began. Between Lake Ontario and Montreal the river divides naturally into five sections. The first is the "Thousand Islands", with 68 miles of deep, lake-like reaches of the river, extending from Lake Ontario to Chimney Point. The second, the International Rapids, covers 47 miles of rapids and swiftly moving water (including the Long Sault Rapids) between Chimney Point and the head of Lake St Francis. The third is Lake St Francis, 27 miles long. The fourth, Soulanges, extends from deep water in Lake St Francis through 18 miles of rapids to deep water in Lake St Louis. Lachine is the fifth. It contains 24 miles of rapids and shoals from Lake St Louis to Montreal Harbour.

Work for the power project was concentrated in the second section, although there was major work in the fourth and fifth as well, with the deepening of the Soulanges and Lachine Rapids. Only the first two sections are along the international boundary; thus Canada's share of work for deepening the waterways was larger than that of the United

FIG. 2. The Long Sault Dam, stretching from the New York State mainland to a point near the head of Barnhart Island. The forebay immediately behind the power-houses, forms part of the 100-square-mile lake created by the flooding of the area on July 1, 1958.
(By courtesy of Ontario Hydro)

States. However, costs for the power project were shared equally. Although New York was already a great harbour state, such a dependable new source of electric power was not to be overlooked. Further, a direct highway to the sea would be open for the first time to the huge industrial centres of the American Middle West.

PRINCIPAL STRUCTURES

To generate power from the International Rapids section of the St Lawrence, it was necessary to utilise the drop in the water-level between the eastern end of Lake Ontario and the power-house site. Because it is spread over a 125-mile stretch, this drop—amounting to 92 ft.—was of little value for power until it could be concentrated at one point. This was done by the construction of the Long Sault Dam, some 3 miles upstream from the power-houses. It stretches from the western end of Barnhart Island to the mainland of the U.S. A curved-axis, concrete, gravity, spillway structure, it is 2250 ft. long and, at maximum height, is 145 ft. above the foundation. It maintains the headpond (some 23,000 million cu. ft. of water at an initial elevation of 236 ft. extending 28 miles from the power-houses to Iroquois Dam), and by-passes water not required for power production.

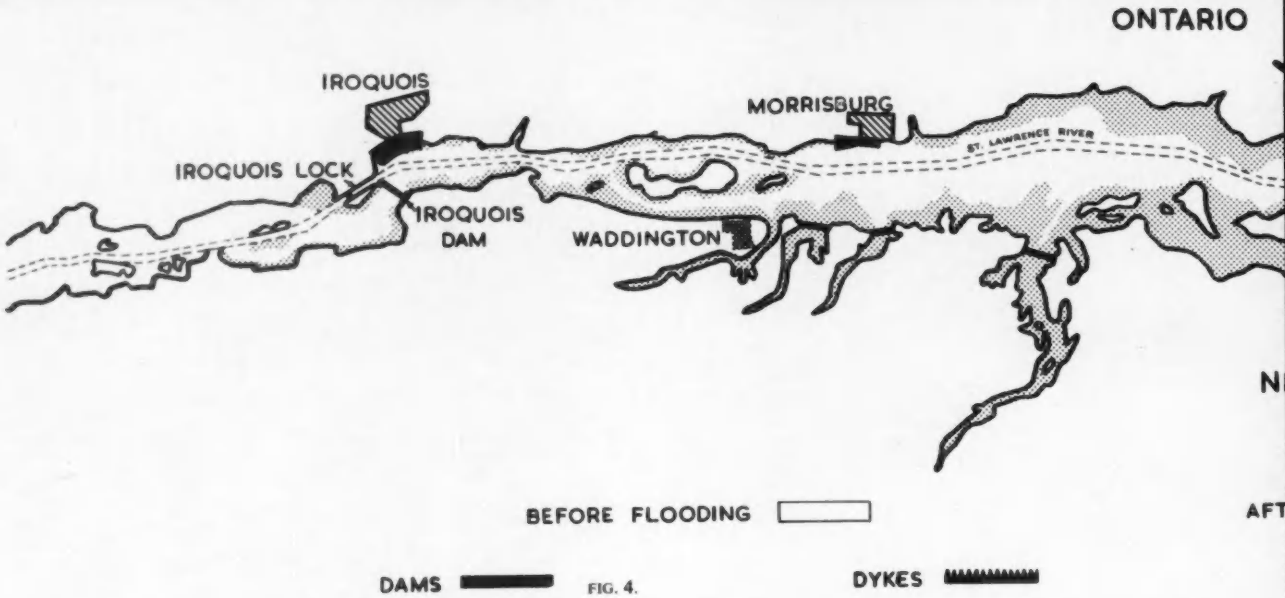
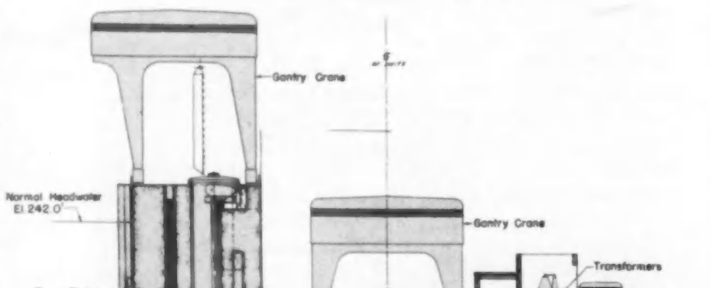


FIG. 4.

The power is generated by the Robert H. Saunders Generating Station of Canada and the Robert Moses Power Dam of the U.S. These power-houses merge at the international boundary, forming a continuous structure which spans the channel between Barnhart Island and the Canadian shore. This structure, 3300 ft. long and 162 ft. at maximum height above the foundation, acts as a gravity dam and combines with the Long Sault Dam in maintaining the headpond. The maximum capacity of its thirty-two generators (sixteen units to each power-house) is 1,880,000 kW; the installed capacity is 1,640,000 kW. The generators are protected by removable hatch covers, rather than by conventional superstructures, to allow easy access.

FIG. 5. Cross-section of the generator at Canada's Robert H. Saunders Generating Station.



The dykes, also needed for maintaining the headpond, are located intermittently along the Ontario shore line north and west of the power-house, and along the New York shore-line starting at the power-house and extending west.

The outflow from Lake Ontario is controlled by the Iroquois Dam, about 25 miles upstream from the Long Sault Dam between Iroquois Point on the Canadian side and Point Rockaway on the U.S. mainland. It is a straight-line structure, 2540 ft. long and 67 ft. high.

ECONOMIC BENEFITS

Already the assurance of low-priced, dependable power has stimulated the economy of the St Lawrence Valley in Ontario and New York. Many new businesses have been established and hundreds of new homes built for a population which has been increasing rapidly for the past four years.

Power produced by Canada's sixteen generators will augment that of Ontario Hydro's fifty-nine generating stations and thus contribute to a vast power pool in southern and north-eastern Ontario. Today, nine out of ten farms in the province are electrified, and Ontario's *per capita* consumption of electricity has reached 5500 kWh annually. By comparison, the *per capita* consumption for the U.S. is 4300 kWh and that for the United Kingdom is 1800 kWh.

All the power to be produced by America's sixteen generators has been sold. In the vicinity of Massena, N.Y., Reynolds Aluminium Co. are constructing a \$100 million plant which is expected to employ more than 1000 workers. The Chevrolet Automobile Co. are building a \$15 million parts plant, scheduled to employ 700 workers, while the Quebec Lithium Co. intend to build a \$3 million plant at Rouses Point.

These are a few of the immediate benefits offered by one of the largest power projects of all time. But beyond this, the prospects of navigation by ocean-going vessels to the Great Lakes is itself a development which promises to revolutionise the economy of the North American continent.

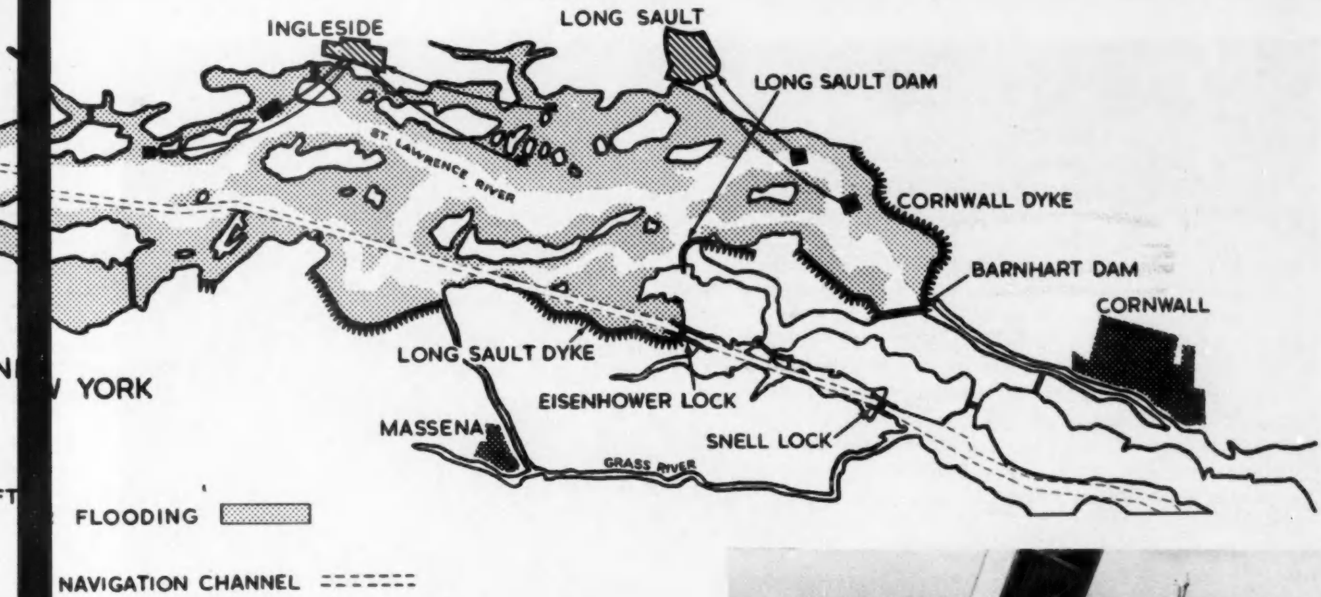


FIG. 6 (*above*). The first lock in the Seaway was completed in 1957. The new system of canals and channels will allow ocean-going ships carrying up to about 9000 tons of cargo to reach the big American industrial centres inland. The cost will be paid in fifty years by tolls. (*Right*), the C.G.S. *Grenville* passes a rolling lift-bridge as it enters the lock chamber.

(By courtesy of the National Film Board of Canada)

FIG. 7 (*below*). The Iroquois Dam spanning the St Lawrence between Iroquois Point and Point Rockaway. The 32 sluices, each of which is 50 ft. wide, are controlled by steel gates. The new village of Iroquois is in the background. Two new villages were created in a resettlement programme which involved 6500 people in Canada alone.

(By courtesy of Ontario Hydro)

FIG. 1. Princess Augusta's house at Kew as it was in the 18th century.

PRINCESS AUGUSTA'S GARDEN

SIR EDWARD SALISBURY, C.B.E., F.R.S.

Director of the Royal Botanic Gardens, Kew, 1943–56

Kew Botanic Gardens were founded 200 years ago on a nine-acre area consisting of Thames sand and gravel. Today the enriched soil nourishes a collection of about 45,000 living plants, and the herbarium at Kew probably contains more than 200,000 "types" of dried plants.

The garden started at Kew House by that remarkably able woman, Princess Augusta, has developed into the most famous, botanically, of all such ventures. This is not because of its age, for a number of public and private gardens were founded much earlier, and indeed, Kew had already attained high esteem during the thirteen years from the time of its foundation to the date of Princess Augusta's death in 1772. The garden has become world famous because of its scientific importance.

Not unnaturally, the earliest collections of living plants were mostly utilitarian, developments from the monastic herb gardens which eliminated the necessity of searching the countryside or relying on dried samples for making medicines and drugs. Gardens of the 9th century, such as that at St Gall in France, were clearly for this limited purpose, and the 12th-century writings of Abbot Neckam of Cirencester recommend the cultivation of a limited number of herbs for the treatment of the monks and of the laity dependent upon them. The larger herb gardens also facilitated the identification of plants, and it is not without significance that the publication of many of the famous herbals coincided with the period when the greatest number of botanical gardens were established in Europe. Though the descriptions of plants in these herbals were sometimes indifferent, the woodcut illustrations were frequently excellent. See, for example, Fuchs (1542), Mattioli (1560), and especially Brunfels (1530).

EARLY BOTANICAL GARDENS

The earliest recorded botanical garden owed its existence, like those at Kew, to private enterprise. The wealthy nobleman, Gaspar de Gabriel, instituted a collection of plants at Padua in 1525. It was this, no doubt, that inspired the Venetian Senate to establish the public botanic garden there 414 years ago, in spite of the fact that the Republic of Venice already had a herb garden founded two centuries earlier. In thirty-six years the garden at Padua acquired some 400 plants. Not all of these were medical plants, although Padua possessed an outstanding medical school; many were plants of other economic importance. One likes to think that this garden played its part when Harvey went to Padua to study philosophy and was led to adopt a medical career.

Zurich (where Gesner worked), founded in 1560, and the garden at Leiden, founded by Clusius in 1577, are two other botanical gardens with traditions going back to the 16th century. Leiden acquired over 1000 species within sixty years, and by 1720, when Boerhaave was director, the number was over 6000. This is remarkable for a garden of only a few acres. The botanical garden at Paris was not effectively established until 1626, and that at Vienna somewhat earlier (1570). Towards the middle of the 17th century gardens were established at Copenhagen (1640) and Upsala (1657). Some 1800 species were cultivated at Upsala but suffered from a disastrous fire in 1702. These gardens were to become famous again when Linnaeus took charge in 1742.

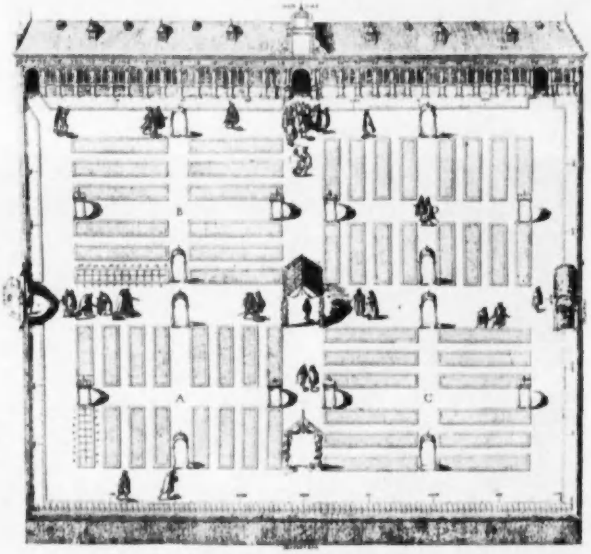


FIG. 2 (*above*). A plan (dated 1601) of the Botanical Gardens at Leiden.
(*Reproduced by courtesy of the Royal Botanic Gardens, Kew*)

In Britain the College of Physicians had a garden in Knight Rider Street in 1614, and in 1677 the Chelsea Physic Garden was established by the Society of Apothecaries "that their apprentices and others may the better distinguish good and useful plants from those that bear resemblances to them and yet are hurtful and other the like good purposes". Although the final phrase might indicate a wider aim, the utilitarian intention was clearly predominant. The botanic gardens founded in connexion with the seats of learning at Oxford (1632), Edinburgh (1680), and Cambridge (about the middle of the 18th century), were all primarily adjuncts to the teaching of *materia medica.*

PLANTS FOR PLANTS' SAKE

Kew was established in the 18th century, as were the botanical gardens at Madrid (1753) and Coimbra (1773). Of all the European gardens which preceded Princess Augusta's garden, the one at Montpellier deserves special mention. This garden was unique in that the native flora of the surrounding countryside was well represented amid the 1300 kinds of plants cultivated there in its early years. Whether this was motivated by the collector's urge, well to the fore in the herbals of this epoch, or by a growing appreciation of species of little or no economic significance, is a matter for speculation.

Princess Augusta had a genuine love of plants and appears to have had something of the modern approach in considering them worthy of study for their own sake. The collections catalogued by John Hill (1768), who only enumerated the rarer exotics, and by William Aiton (*Hortus Kewensis* 1789 and 1810–13) indicate a catholicity of approach that was perhaps the salient feature contributing to the success of the garden. The Princess's ability was

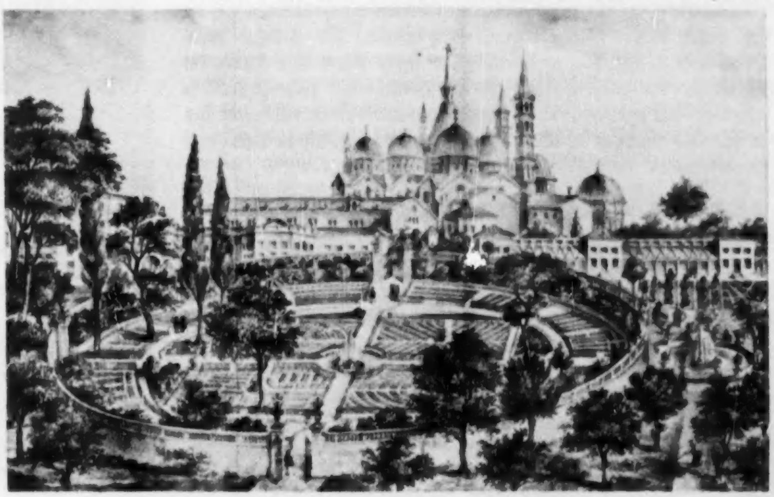


FIG. 3 (*right*). An 1842 drawing of Padua Botanical Garden
(*Reproduced by courtesy of the Royal Botanic Gardens, Kew*)

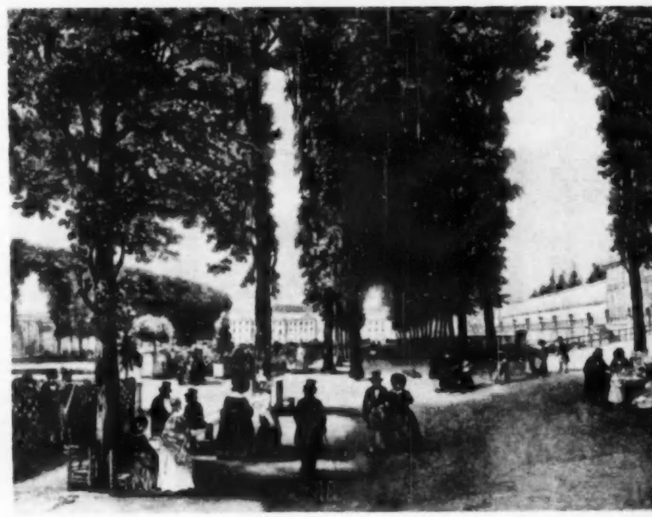
FIG. 4 (*above*). Le Jardin des Plantes, Paris, 1794.

further manifest in the choice of those upon whose advice she relied. Her botanical mentor was the Earl of Bute who was a good scientist if a poor politician—a combination which can be easily paralleled today. In the layout of the garden the Princess was aided by the exceptionally gifted Sir William Chambers whose good taste is still evident in the orangery at Kew and in the gardens of Stour Head. William Aiton was engaged as curator to supervise the culture of the collections. When Princess Augusta died he took charge of the combined gardens of Kew House and Richmond Lodge, thereafter known as Kew Gardens.

But no less important in the success of Kew was the fact that Princess Augusta imbued her son, George III, with similar tastes and aspirations. After her death the Earl of Bute retired and George III replaced him with Sir Joseph Banks. It was he who initiated the practice, carried out to this day, of maintaining overseas contacts. He was also responsible for the large number of exotic plants brought in by collectors from all over the globe. Sir Joseph was President of the Royal Society for forty years and Director of Kew—in fact, though not in name—for nearly half a century. He accomplished more than most in developing the economic aspects of the gardens while keeping in sight the broader aim—the advancement of knowledge.

BOTANY FOR THE PUBLIC

When the gardens passed from private to public ownership in 1840, Sir William Hooker, Professor of Botany at Glasgow and leading pteridologist of his day, was appointed director. He developed the parklands surrounding the gardens so that they expanded from 15 to 260 acres. The next expansion occurred when Queen Victoria presented the Queen's Cottage Grounds. The gardens had declined after the death of Sir Joseph Banks, but Sir William Hooker revived the tradition that Princess Augusta had initiated. The Hookers also developed to the full the equipment



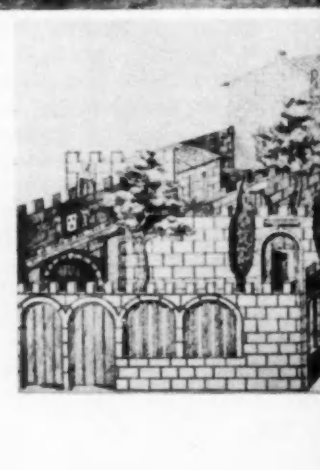


FIG. 7 (*right*). Montpellier Botanical Gardens in 1596.
(Reproduced by courtesy of the Royal Botanic Gardens, Kew)

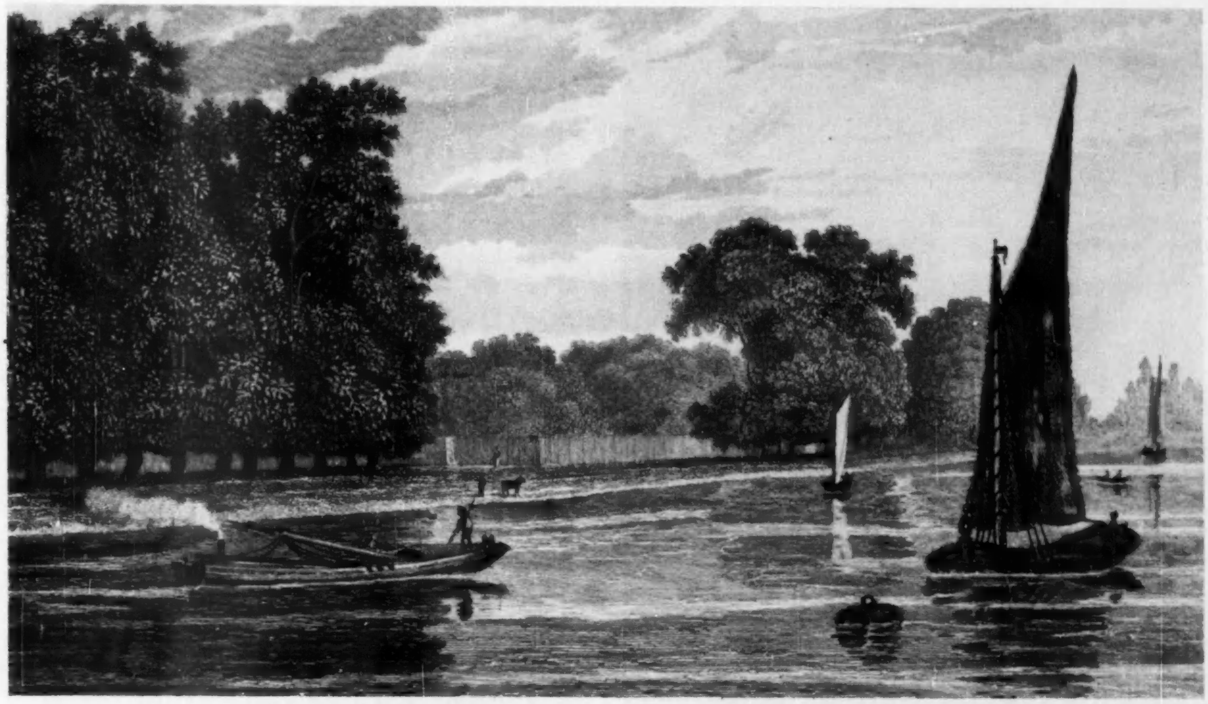


FIG. 5 (*above*). Kew Gardens in the 18th century, as seen from the River Thames.

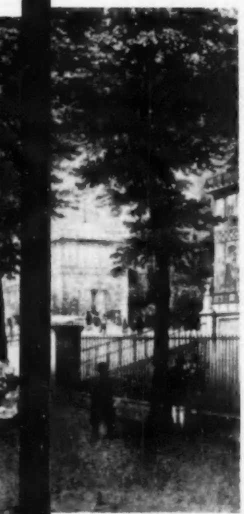
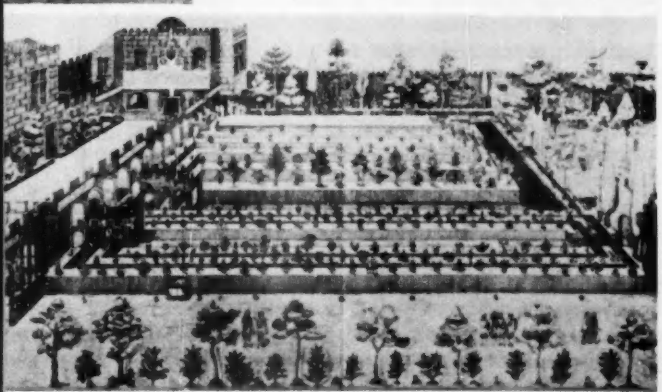


FIG. 6 (*left*). Le Jardin des Plantes, Paris, 1840.



required for plant identification: an herbarium of authenticated specimens to supplement the living collections, a botanical library with the emphasis on taxonomy, and a museum of plant products. All of this was made possible through the generosity of many donors, especially among the Hookers' overseas correspondents.

Yet the supreme position which Kew has come to assume, from the point of view of identification, was largely an outcome of two activities. Firstly, the production by Bentham and Hooker of the *Genera Plantarum* from 1862 to 1883, containing the Latin descriptions of all the genera of flowering plants known at that period. The second and even more important event was the compilation of the species of flowering plants already described, and of the sources where their diagnostic features were first stated. This *Index Kewensis* was due to the wisdom and foresight of Charles Darwin who also paid its expenses. The *Index*, with its supplements, has become an essential tool of international importance to all workers in taxonomy, and has augmented exchange with systematic botanists in other countries. The result was a great enrichment of the literature and specimens of the Kew collections—especially of types and co-types—which was beneficial to giver and recipient. Another result is that many botanists from all over the world come to work at Kew, since the wealth of its collections often provides in a single institution what would otherwise entail trips to many. Thus Kew has achieved its position as much by the generosity of others as by its own efforts.

Kew is a botanical Mecca of which we and the Commonwealth have the right to be proud—but only as an international possession which we hold in trust for the advancement of science. Because Princess Augusta laid good foundations, in spite of the more limited concepts of her epoch and interests, they have successfully served to bear the superstructure of two centuries of development and expansion.

FIG. 4 (*above*). Le Jardin des Plantes, Paris, 1794.

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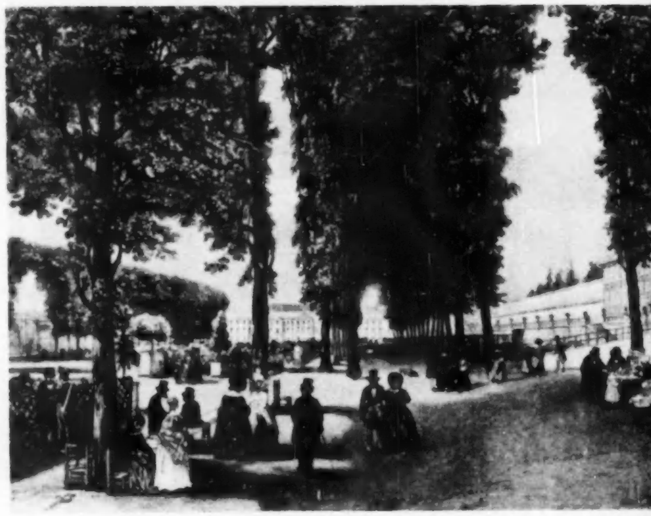

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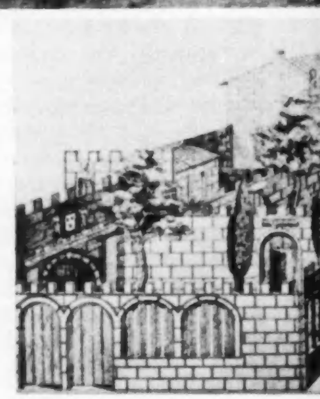

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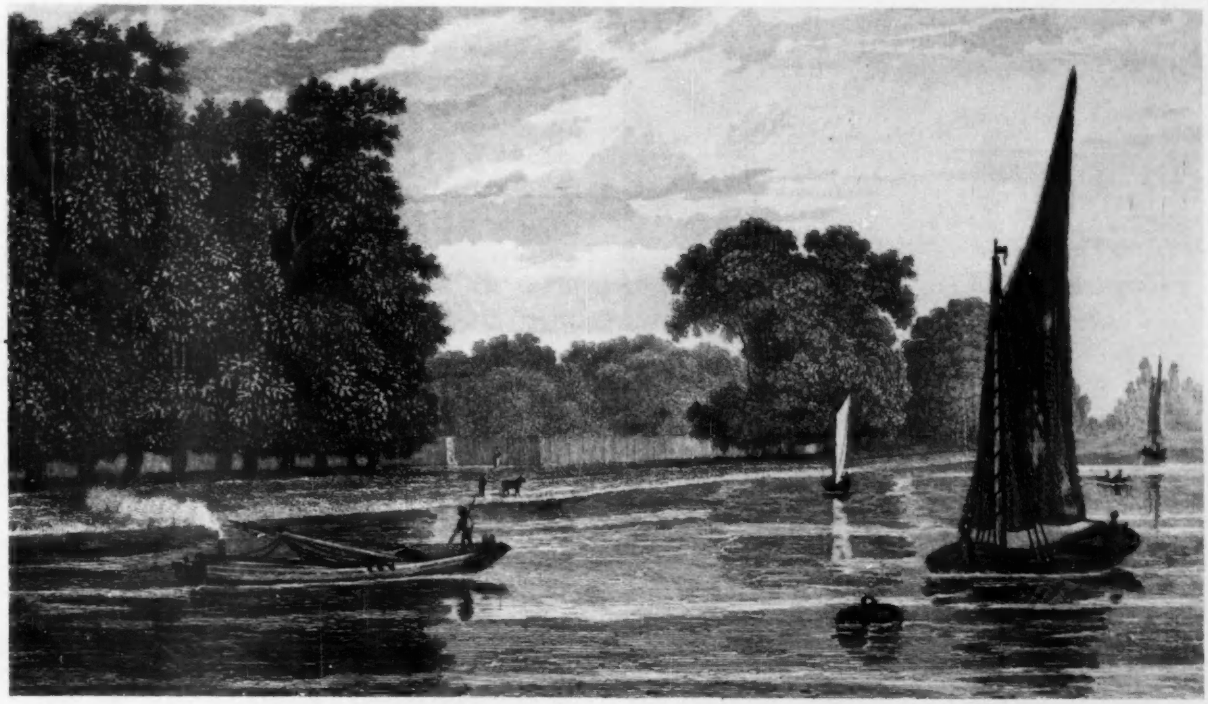

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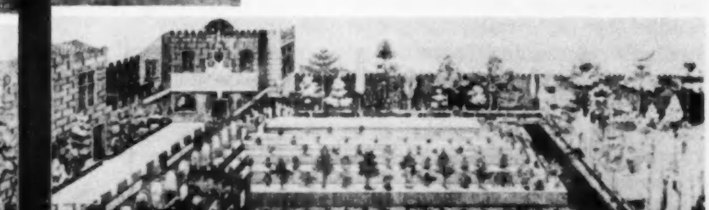

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"THE DANGEROUS DESERTS OF SPACE"

P. HOWARD, O.B.E., M.B., B.S.

R.A.F. Institute of Aviation Medicine, Farnborough

Eighty-four years ago three men made an experimental flight in a gas-filled balloon called Zenith. *The tragic consequences of that flight, the first deaths in space, bear dramatically on the present-day attempts to enter outer space with manned ships.*

FIG. 1. ". . . an incident of Mr Glaisher's great ascent, with Mr Coxwell, at Wolverhampton, on September 5, 1862, when they attained the elevation of 29,000 ft., and Mr Glaisher suffered a momentary attack of faintness, which deprived him of the power of speaking or moving, and even blinded him for an instant, though he never lost consciousness. He would perhaps have died but that Mr Coxwell, having climbed to the hoop above the car, opened the valves of the balloon, and let out some of the gas, when they rapidly descended to a more tolerable region."
(*Taken from* The Illustrated London News, *January 15, 1870, p. 84*)

A little more than a year ago, in Operation Manhigh, David Simons set out to explore some of the problems which will confront space-travellers. He took with him a great deal of equipment; some of it to protect him against the cold thinness of the air at high altitude, and more to give him a chance of escape should the primary defences fail. He reached a height of more than 100,000 ft., and so became the "highest man alive". His vehicle was a balloon.

Eighty-four years ago, in the balloon *Zenith,* Gaston Tissandier, Joseph Croce-Spinelli, and Theodore Sivel made an ascent which was as surely a landmark in the exploration of space as that of Simons. Although the altitude they reached was but one-fourth that of the Manhigh flight, only one of the three men returned alive. The deaths of Sivel and Croce-Spinelli were, in a sense, related to the survival of Simons and of a host of future travellers into space, for they raised physiological issues which are of continuing application to aviation. It is therefore of some interest to look back, in the light of present knowledge, to the events which led to the tragedy of the *Zenith.*

In 1875 the Société de Navigation Aérienne sponsored two flights by the *Zenith;* the one was to be an endurance flight and the other an ascent to great height. The first of these voyages was an outstanding success. Carrying Croce-Spinelli, Jobert, Tissandier and his brother Albert, and Sivel (who had been responsible for the construction of the balloon), the *Zenith* was aloft for 28 hours and 40 minutes, thus handsomely exceeding any previous flight. The expedition was not intended to be purely a record-breaking attempt, however, and some observations were made on the composition of the atmosphere. Similar measurements were to be made during the second, high-altitude flight. Tissandier was only included in the party for the latter ascent after strong representations by Sivel and Croce-Spinelli to the president and secretary of the sponsoring society. These two officials pointed out that the presence of Tissandier would deprive the balloonists of a quantity of ballast, and they were reluctant to include any unnecessary weight which could not be jettisoned to increase the height reached by the *Zenith.* Croce-Spinelli's reassurances to Tissandier at this time were unhappily prophetic. "There must be three of us," he said, "the better to confirm the results. Besides, you must breathe oxygen in the upper regions, so you can say that it is both efficacious and necessary." Just how necessary it was, Tissandier was soon to discover.

A "POWERFUL CORDIAL"

The apparatus which the balloon carried included a variety of scientific equipment: thermometers and barometers, a spectroscope for the detection of water vapour, and a large aspirator to draw air through tubes of potash for a later estimation of the carbon dioxide content of the atmosphere. To provide some objective evidence of

the altitude reached by the balloon, there were also eight "witness" barometer tubes, packed securely in sawdust and locked in a wooden box. Most important of all were three small balloons containing air with 70% of added oxygen, each connected through a wash-bottle to a mouthpiece. There will be more to say of these later, but they were carried on the advice of Paul Bert, whose research into the efforts of decreased barometric pressure is still the great classic of aviation physiology. In March of the previous year both Croce-Spinelli and Sivel had visited Bert's laboratory to gain some experience in his decompression chamber, and during an ascent to a simulated altitude of 7300 m. (24,000 ft.) they had both become convinced of the benefit conferred by breathing oxygen. A few days later the two men had made an actual ascent to the same height, and Paul Bert had provided them with mixtures of air and oxygen, which they used almost continuously above 3600 m. (11,800 ft.). It is hardly surprising that they felt confident of their ability to go even higher with the help of this "powerful cordial".

The ascent of the *Zenith* to 3300 m. (11,000 ft.) was uneventful, but at that height gas began to escape from the open end of the envelope. The smell was pronounced, and although Tissandier and Sivel were not inconvenienced by it, Croce-Spinelli noted that he felt depressed; a symptom which he blamed on the gas. The coincidence that the three passengers all became unwell soon afterwards led many to believe that the escaping gas played a part in the deaths of Sivel and Croce-Spinelli. Tissandier strenuously denied this theory, pointing out that he had on several previous flights been extremely conscious of a strong smell of gas without noticeable ill-effects. Despite Tissandier's conviction, it is possible that the deaths of his two companions were hastened by this earlier incident, and more will be said on this subject shortly.

By the time that the *Zenith* had reached 7000 m. (23,000 ft.) all the members of the party were showing signs of a lack of oxygen. Tissandier felt dejected, and disinclined to work the aspirator which was his especial care; Sivel began to close his eyes for a few moments at a time, and had to force himself into activity. Croce-Spinelli was apparently the least affected and continued to peer through his spectroscope, but when he discovered an absence of the lines of water vapour, his excitement was unnaturally great. His face was "radiant with joy" and he "earnestly entreated" Tissandier to read the barometer and thermometer. His reactions, in fact, were out of proportion to the magnitude of the simple observation he had made. Tissandier's comments on the state of his companions are probably reliable, for he alone was using the oxygen mixture at intervals.

There had been little time for making the physiological studies for which Paul Bert had asked; the only data were taken at about 5000 m. (16,000 ft.), and these consisted merely of incomplete records of pulse and respiratory rates. All three travellers had a fast pulse at the time; Sivel's heart-rate, in fact, was almost twice its normal value. This increase can be accounted for in part by the excitement and exertion of the occasion, and so can the slightly raised respiratory rate of Tissandier, but anoxia, lack of oxygen in the blood, was undoubtedly the prime cause.

Despite his intermittent inhalation of oxygen, Tissandier found the effort of writing almost too much for him. His notes, which he had no clear recollection of making, were almost illegible, but he observed that his colleagues were drowsy, and that Sivel's breathing was laboured. At about this time all three began to use the oxygen mixture sporadically, which revived Sivel so much that he remembered his ambition to go yet higher. His face lit up, and he asked Tissandier for the barometer reading. It was 300 mm. of mercury, equivalent to 7540 m. or 24,500 ft. Sivel, impatient to go on, asked whether he should throw out more ballast. The responses he received show how severely affected were his friends. Tissandier told him to please himself, while Croce-Spinelli could not apparently find the strength or the words to speak, and contented himself with nodding. Already, there was little sign of the three enthusiastic adventurers who had set out so bravely. Three of the remaining five bags of ballast were voided, and the balloon ascended rapidly. Tissandier remembered propping himself against the side of the basket, but although he retained consciousness and some power of thought for a

FIG. 2. A typical scientific balloon ascent of the early years of the present century. This sketch of the balloon *Humboldt* was drawn by Major von Gross, Commander of the Prussian Balloon Battalion at Tegel, near Berlin. Perhaps the author of the sketch has included himself on the right of the gondola. The details seen on the balloon are as follows: (*a*) Wet and dry bulb thermometer; (*b*) Sunshine thermometer; (*c*) Telescope to read (*a*); (*d*) Thermograph; (*e*) Mercury barometer; (*f*) Barograph; (*g*) Aneroid barometer; (*h*) Photographic camera; (*i*) Container for scientific instruments; (*k*) Ballast; (*l*) Anchor and rope.

(Photograph from "Die Eroberung der Luft", Berlin 1909)

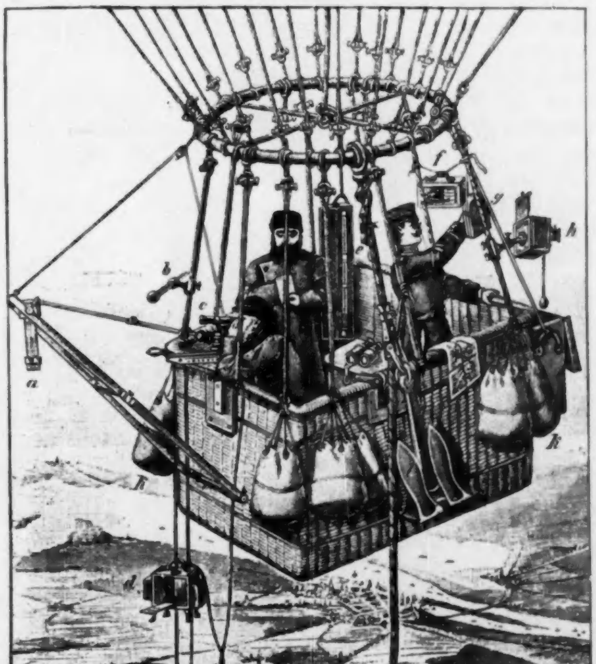


FIG. 3. The balloon basket of the *Zenith* during the fatal ascent on April 15, 1875. On the left, Sivel is cutting the rope holding the ballast sack; in the centre, Tissandier, founder and editor of *La Nature*, observes the barometer; and on the right, Croce-Spinelli, having made some spectroscopic observations, is about to inhale oxygen from the small inflated balloons via the wash bottle he is holding in his left hand.

little longer, he grew rapidly so feeble that he could not even turn his head to look at his fellows. He felt that he needed oxygen, but the effort of reaching for the mouthpiece was beyond his powers. The barometer was within his line of sight, and he watched its needle anxiously as it crept past 290 mm., then to 280 mm., then on. They had reached and exceeded the 8000 m. of which they had all dreamed. Tissandier could not open his mouth to tell his friends; it is doubtful whether they could have heard.

ZENITH DESCENDS

Suddenly, Tissandier's eyes closed, and he, too, fell unconscious to the floor of the basket.

Half an hour later he awoke, to find that the balloon was falling rapidly. He jettisoned some ballast to slow the descent, and was able to write in the log that Sivel and Croce-Spinelli were lying inert.

Even Tissandier was still far from recovered, and he lost his senses once more. At the same time Croce-Spinelli came to and shook Tissandier back to awareness, although he was still incapable of action.

Croce-Spinelli threw out the rest of the ballast, some blankets, and finally the aspirator, in an attempt to check the speed of the descent. (Tissandier records that the aspirator fell close to a woman sitting on the grass with her children. He points out, however, that Croce-Spinelli had done nothing contrary to the rules of the air, because the aspirator did not weigh more than 17 kg. (36 lb.), and the descent was extremely rapid.)

The subsequent behaviour of the balloon is largely conjectural, for Tissandier soon collapsed once more.

It is certain that the *Zenith* climbed again, and later examination of the two surviving witness barometers established the greatest altitude reached at between 8540 and 8600 m. (about 28,000 ft.). It is also certain that Tissandier was insensible for about an hour and a half, for when he awoke it was 3.30 p.m. The balloon was descending once more, and at a frightening speed. Sivel and Croce-Spinelli still lay at the bottom of the basket. Tissandier crawled over to rouse them. He lifted their heads from their covering of rugs. The faces were black; the mouths filled with blood. The full realisation that they were dead did not come to Tissandier at once. He tried wildly to slow the frightening fall of the balloon which was by now very near the ground. At last he succeeded in finding and freeing the anchor, and was able to break the shock of the impact. He climbed from the basket, leaving the bodies of his companions in the grotesque postures which they had assumed when the *Zenith* struck, and then he, once more, collapsed on the ground. Several of the local inhabitants came running to help Tissandier, and under his direction the bodies of the two men were lifted from the basket. Tissandier now realised the enormity of the situation and he behaved like one demented, throwing himself first against one corpse, then against the other, imploring them to speak. He noticed a loud buzzing in his ears, and that he had lost his hearing; these symptoms he attributed with the rest, to his state of anguish.

They were more probably due, however, to the condition known as barotrauma. As the barometric pressure increases during a descent from altitude, the flap valve guarding the passage between the mouth and the middle ear tends to close. The resulting pressure difference across the ear-drum causes pain, deafness, and in severe cases, rupture of the drum. Very mild symptoms of barotrauma are still common in airline passengers as the aircraft descends.

The following morning he was calm enough to write a full report of the flight to the President of the Société de Navigation Aérienne, and to include his opinions on the mode of death of Croce-Spinelli and Sivel. The bodies were carried back to Paris two days later, and the funeral took place in the presence of a multitude of people on April 20. Most of the prominent scientists of the country took part and many speeches were made praising the courage, the integrity, and the devotion of the unfortunate victims. Tissandier wanted to make a last public obeisance to his friends but as he approached the grave he was overcome with grief, and could do little more than repeat their names before he was led away. Soon after, with scientific detachment, he set out to write a complete account of the whole affair with a reasoned account of his findings and conclusions. It was published a fortnight later, in the scientific journal *La Nature*, of which Tissandier was founder and editor.

AN APPARENT ANOMALY

Croce-Spinelli, and probably Sivel, died during the second ascent of the balloon, although the altitude reached on that occasion may have been less than that attained during the first climb. Tissandier concludes that their deaths were due to anoxia and quotes the experiments of Paul Bert as evidence for this opinion. He suggests, reasonably enough, that it is possible to survive relatively short exposures to low barometric pressures, but that the stress of almost two hours of continuous exposure to high altitude is too severe to be borne. No previous flight had exceeded 7300 m. (23,600 ft.) and the times spent at great height had all been relatively short. (It is true that Glaisher claimed to have reached 11,000 m. (36,089 ft.), but this figure was achieved by assuming a constant speed of ascent and descent of the balloon during the time that its occupant was unconscious.)

Tissandier was rightly convinced that his friends would not have perished had they been able to breathe oxygen. At the very time when they were most in need of the gas, their strength was insufficient for them to reach the breathing tubes. He attributed his own salvation to his particular temperament and thought that his own collapse might have been more complete, with a fuller and thus more beneficial suspension of his respiratory functions.

There are many points of interest in the story of the *Zenith*'s high-altitude flight, and in Tissandier's conclusions, but before these are discussed, attention must be drawn to one apparent anomaly. In Tissandier's account, the heights at which the various events took place are quoted in metres and there are only very occasional references to the barometric pressure. Where direct comparison is possible, as for example when the maximum altitude reached by the balloon is mentioned, a discrepancy is apparent. The relationship between pressure and altitude assumed by Tissandier and his contemporaries was, by modern standards, wrong, and it tended to overestimate the height reached by the *Zenith*. The correction needed is small, amounting to a reduction of about 1500 to 1700 ft.

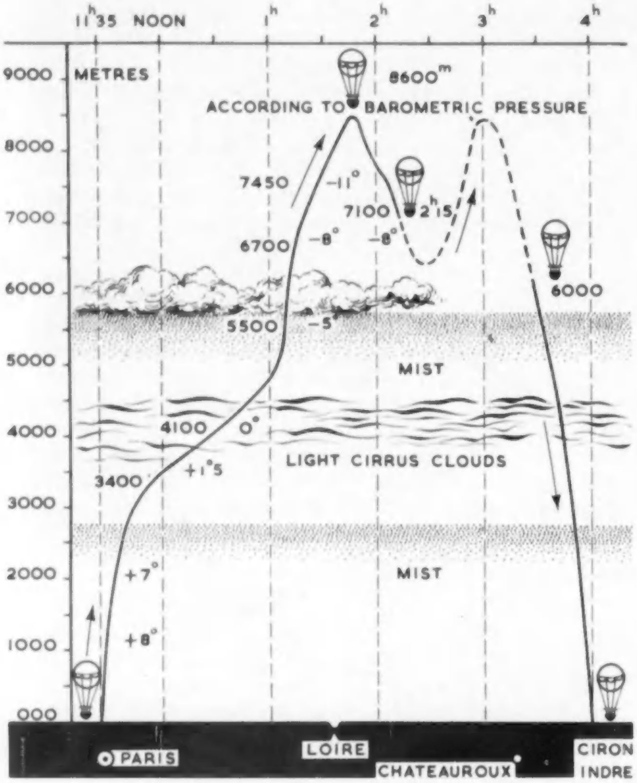


FIG. 4. Diagram of the ascent of the *Zenith* on April 15, 1875

in the maximum altitude of 28,000 ft. claimed by Tissandier.

The first occurrence of physiological significance during the flight was the escape of gas from the envelope. Tissandier was inclined to dismiss this lightly, as a common inconvenience of ascent, and one which could have played no part in the later tragedy. It is virtually certain, however, that the lighting gas used for inflating the balloon contained a high proportion of carbon monoxide; this has a great affinity for haemoglobin, and consequently interferes with the carriage of oxygen by the blood. The elimination of carbon monoxide is a slow process, and it is therefore possible that all three members of the party were suffering from mild coal-gas poisoning which would aggravate the effects of the later oxygen lack.

The first unequivocal signs of anoxia apparently occurred at 7000 m., or 23,000 ft., but it must be remembered that the recognition of abnormal behaviour requires a normal observer. One of the most dangerous features of oxygen lack is the loss of judgment which it produces; not only does the sufferer fail to recognise the peculiar action of others, but he regards himself as unusually rational and clear-headed. This stage is usually reached at a height of 15,000 to 18,000 ft. (4500 to 5500 m.) and it is likely that had Tissandier's critical faculty not been impaired he would have noticed some unusual behaviour on the part of the others at a height well below 7000 m. It is insignificant that his notes refer first to the fact that he had breathed oxygen, and then to the laboured breathing and drowsiness of Sivel and Croce-Spinelli. Without the help of the gas mixture he would probably have been unable to write at all, for most men rapidly became stuporous at this altitude and lose consciousness after a relatively short time.

The earlier feeling of elation and of power gives place to indifference and irritability. The exact course of events and the order in which symptoms occur vary considerably from person to person, and the fact that Croce-Spinelli was still lively and excited when his friends were languid and depressed does not necessarily denote a high resistance to anoxia. His childish delight at the spectroscopic findings was certainly pathological, and had either of the others spoken a sharp word of disbelief or rebuke he would probably have burst into tears. At 7500 m. (24,500 ft.) Tissandier was in the grip of severe oxygen lack. He was virtually paralysed and suffering from the mild hallucinations which often precede complete unconsciousness. This is not surprising, for a sudden exposure to that height will produce unconsciousness in a matter of minutes in all but the most resistant of men.

It is interesting to read that both Tissandier and Croce-Spinelli recovered for a while when the balloon descended to about 22,000 ft. Croce-Spinelli at least had enough strength to shake his companion, and he clearly did not realise the danger of his action. Even the smallest amount of exertion by a man suffering from anoxia is sufficient to tip the scale towards collapse. During the war, for example, it was not uncommon for a crew member, going to help an unconscious fellow, to fall comatose from the effort of moving or lifting.

Tissandier was convinced that Sivel was still alive at this time, but it is quite possible that he had already succumbed. Sivel seems to have been the first to lose consciousness, and an exposure of at least 40 minutes to a barometric pressure of less than 300 mm. of mercury might well have killed him. It may be, however, that he stayed alive, but unconscious, only to die with Croce-Spinelli from the prolonged anoxia when the *Zenith* climbed once more to around 26,000 ft.

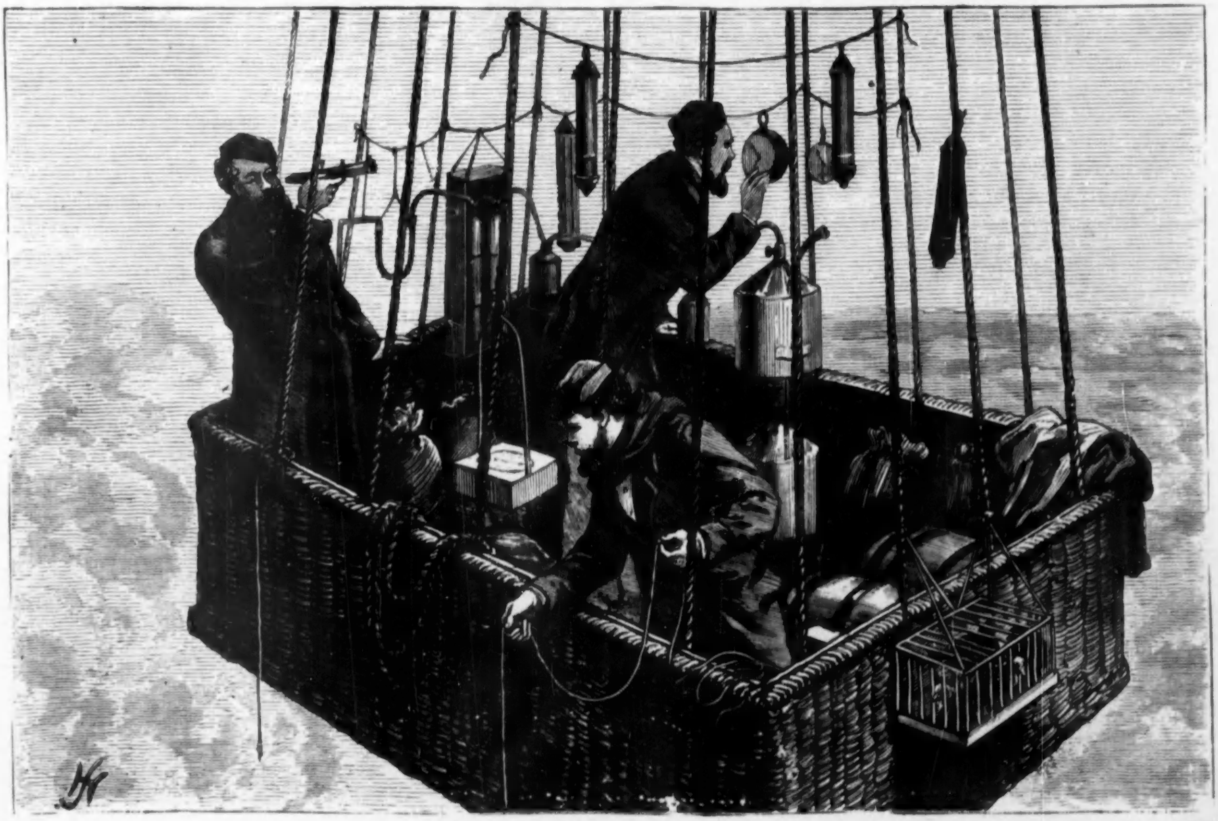
The deaths were undoubtedly due to anoxia, and it is at first sight strange that they should have occurred when oxygen had been provided for the flight. The gas mixture available contained 70% of added oxygen and it is possible to calculate the height which could safely be reached with such a mixture. At sea-level the partial pressure of oxygen in the lungs is approximately 100 mm. of mercury, and to maintain this value at 26,000 ft., the air would need to be enriched with about 40% of added oxygen. The 70% mixture used in the *Zenith* would keep the oxygen pressure in the lungs at the sea-level even at a height of 29,000 ft., or nearly 9000 m. There is no need to satisfy such stringent physiological conditions. The Royal Air Force considers that no significant impairment of performance occurs if air is breathed at heights of up to 10,000 ft. (3000 m.) provided that night vision is not needed. Under these conditions the pulmonary pressure of oxygen is about 60 mm. of mercury, the exact figure depending upon the degree of overbreathing which takes place as a compensation for the anoxia. Assuming that a similar degree of oxygen lack would have been acceptable in the *Zenith*, it appears that the mixture with which they were provided

would have served the passengers up to an altitude of 35,000 ft. or about 10,800 m. Clearly, they did not perish because their supply of gas was not rich enough.

A MYSTERIOUS OVERSIGHT

The oxygen was contained in three small balloons, but there is no record of their capacity. In an illustration of the *Zenith* at high altitude, the bags appear to be about 2 ft. in diameter, which would give them a volume of approximately 120 litres. It is not known, of course, whether the artist took account of the expansion which would be produced by the ascent, and all that can be said is that the volume of gas available probably did not exceed 150 litres for each of the voyagers. Now, even under resting conditions, the ventilation volume is about 10 litres per minute, and an increase in the rate and depth of breathing is a characteristic feature of anoxia. Tissandier's few observations show that even at the moderate altitude of 5000 m. (16,000 ft.) some overbreathing was present. Taking into account the excitement of the occasion, and the work of manipulating instruments and moving about, a requirement of 20 litres a minute for each man is a conservative estimate. This means that for a flight of which nearly two hours and a half were spent above a height where oxygen was essential, only a six minutes supply was available. This seems the more incredible when it is remembered that Croce-Spinelli and Sivel were convinced of the necessity of extra oxygen by their experience at Paul Bert's laboratory. Apparently, they had grasped the principle that anoxia could be prevented by a suitable gas mixture, without appreciating the need for continuous use of the gas. It is perhaps understandable that these two engineers should grasp the physics and ignore the physiology, but it is surprising that Paul Bert, who was responsible for the use of oxygen in this and in previous ascents, should have allowed the expedition to set out with a totally inadequate quantity of gas. The key to the whole tragedy lies in the answer to this mysterious oversight. At the time when the apparatus for the *Zenith* was being assembled, Bert was away from Paris, and his advice had to be sought by letter. He recommended the 70% oxygen mixture, but it was not until later that he was informed of the volume of gas to be taken, which, according to his recollections, was 150 litres. Bert immediately sent a letter to Croce-Spinelli warning him of the pitiful inadequacy of the supply. He pointed out that for three men the consumption would be at least 20 litres a minute (a very optimistic underestimate) and that the supply would therefore not last long. Perhaps because of a natural reluctance to delay the flight while more satisfactory arrangements were made, Croce-Spinelli and the others interpreted Bert's letter as meaning that the oxygen mixture should not be used until the last possible moment. It was, without doubt, the loss of insight and the euphoria which anoxia commonly produces that delayed the "last possible moment" until physical strength could no longer match mental resolution.

FIG. 5. Another view of the *Zenith* during the descent, published in *The London Illustrated News* in 1875. On the left, Croce-Spinelli; in the centre, Tissandier is tapping the barometer; and on the right, Sivel.



The final puzzle is the survival of Tissandier. Various theories have been put forward to account for his escape, including his own suggestion that his unconsciousness was more complete and exerted some protective action. Neither this, nor his observation that he had not eaten before the flight, carries much conviction as an explanation. The simple truth is that there is a very wide variation between individuals in their tolerance to oxygen lack. A degree of anoxia which will lay one man senseless on the floor may leave another still capable of moving about, albeit rather drunkenly. There is no way of knowing how Tissandier would have fared had he been in Bert's decompression chamber with Croce-Spinelli and Sivel, but from the story of the *Zenith* it is not unreasonable to suppose that he would have proved more resistant to the overpowering effects of anoxia.

Flight at 25,000 ft. or so in a balloon is clearly very different from orbiting the Earth in a satellite at a height of several hundred miles. The physiological problems of aviation have grown both in number and in complexity since the time of Tissandier, and in general the solutions have kept pace with the problems. To a limited extent this is also true of anoxia. As the altitudes which can be reached have increased, so the development of oxygen equipment has gone on, until pressure garments or "space-suits" have superseded the simple face-mask. But, just as in Tissandier's day, it is the failure of this equipment which is most to be feared, and for the same reasons. Short of sudden disintegration of the structure, most of the calamities which can occur in modern aircraft can readily be recognised and some action can be taken by the pilot. The insidious onset of oxygen lack, and the loss of insight which it engenders, lead to a disregard of the danger signs, and the final realisation may, as in the case of Croce-Spinelli and Sivel, come too late. The future is unlikely to bring any startling solution to this problem, for mechanical indications of a lack of oxygen are equally likely to be ignored. It is quite certain that death from anoxia will overtake not a few of those who were described, at the funeral of the *Zenith* victims, as "d'autres, plus heureux, qui exploreront un jour ces dangereux déserts de l'espace".

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FIG. 6. Tissandier, the sole survivor, above; Sivel on the left, and Croce-Spinelli on the right.

SCIENCEMANSHIP

DONALD MICHIE, D. Phil.

(Department of Surgical Science, University of Edinburgh)

Prof. C. Northcote Parkinson gave us the Law of Business Administration and Stephen Potter, the Law of Games. The research scientist will be grateful for Murphy's Law on how to make scientific experiments behave scientifically.

The latest book on How to be a Good Scientist is by Prof. D. J. Ingle of Chicago, U.S.A., and has the title, "Principles of Biological and Medical Research". At the end I found myself wondering why it had so little to add to the admirable earlier studies of Beveridge ("The Art of Scientific Investigation") and of Wilson ("An Introduction to Scientific Research"). Perhaps it is not so easy to break fresh ground in this field. However, I am not entirely convinced of this.

MURPHY'S LAW

I think that the deepest and most durable impression which the research man's mind sooner or later receives is how unexpectedly, how unjustly, how distressingly difficult it seems to be to discover or prove anything at all. The research worker would be spared much early perplexity if his formal instruction included a sound treatise on Murphy's Law.

This important Law is described by H. B. Brous Jr. in the September number of *Astounding Science Fiction* as stating, "If anything can go wrong, it will." Research men among my readers will instantly recognise the truth and generality of this Law, even if they have not previously come across its verbal formulation. But having recognised it, what to do about it? Ingle's book, in common with those of Beveridge and of Wilson, has no definite proposals to make.

Here, then, is a suggestion, offered as a stimulus to others interested in this uncharted territory. The moment to take account of Murphy's Law is clearly when you are planning a new investigation. You have worked out how much material will theoretically give you the required amount of information. We will call this theoretical estimate x. x may be the number of rats to be treated, or of acres to be sown, or of soil samples to be collected, and so on. You then attempt to make rational allowance for all the things which might go wrong. While judging any specified mishap to be highly improbable, you might yet consider that the joint effect of all the improbable mishaps might amount to, say, a possible 30% wastage. You therefore decide to budget for 1·43 times the theoretical estimate (after 30% wastage, $1{\cdot}43x$ becomes x), and the multiplier you use (in this case 1·43) I call the Rational Multiplier, R.

$M=R^2$

It is at this stage that we usually finalise our plans, and live to regret it. It turns out that although some of the possible hazards did not materialise, we had forgotten that a proportion of the rats might have fatal convulsions on hearing a whistling kettle, and that a colleague might mistake some of the clearly labelled organs stored in the refrigerator for goldfish food, and act accordingly. It is before any of this happens that Murphy should be consulted. Having quizzically surveyed the wreckage of many an experiment, I assert that the needed prophylactic lies in the use of the *Murpheian* multiplier, M, in place of R, to which it is related by the simple expression $M=R^2$. In our hypothetical case, supposing that the inexperienced (entirely theoretical) man would procure 100 rats from the dealer or animal house, the "rational" man would procure 143, but Murphy would procure 204.

The expression $M=R^2$ rests on more than empiricism. It was derived, with the aid of my colleague, Anne McLaren, from certain theoretical considerations. These involve the idea that the Rational Multiplier depends on the number of discrete risk-bearing operations into which the total experiment can be broken down. If the rationally foreseeable risk attached to each of these is assumed to be accompanied by an independent, unforeseen, Murpheian risk of equal magnitude, then the above equation follows. Of course, the assumption is crudely approximate. But it is a beginning.

NECESSITY OF IDLENESS

Beveridge has emphasised the need of the research man to lie fallow for periods of time, and quotes J. Pierpont Morgan as saying, "I can do a year's work in nine months, but not in twelve months." Unfortunately, he offers no concrete suggestions. A former colleague at one time installed a camp bed in his lab so that he could lie down when he felt tired or lazy. His Departmental Head disapproved, but I think that the idea is interesting.

An allied problem is the Visitor Menace. I knew a famous man of science who, when a self-invited visitor was in the offing, would retire to the cloakroom. He took with him his papers and books, and emerged only when the "all clear" was sounded. I find no reference to the cloakroom manoeuvre in Ingle's book, and Beveridge and Wilson are also without practical recommendations.

The visitor menace is an expression of a general, and truly paralysing, affliction which overtakes most research men in their mature years. This is the Earnestness of being Important. Ingle says, "The early years in the laboratory are the golden years for many scientists. After he becomes known, the volume of mail, telephone calls, number of visitors, organisational activities, including committees by the dozens, and demands for lectures, reviews, and community activities grow insidiously and will destroy the creativity of the scientist if unopposed." But how to oppose them? In a delightful essay on "Heads of Research Laboratories" (translated in S.C.R. *Soviet Science Bulletin*, 1957, vol. 4, p. 1–6) the Soviet Academician A. L. Kursanov utters a similar warning: "They come to us,

these administrative commitments, of their own accord in the fullness of time, and the less we want them the sooner they come." But he also fails to advance a concrete plan of self-defence for the research man.

FIVE PRINCIPLES

If only to start the ball rolling, here are five principles of evasion, not yet tried and tested, but perhaps deserving of trial.

1. No committees.
2. No refereeing.
3. No editing.
4. No book-reviewing.
5. No invited papers.

Special dispensation can possibly be granted for anything for which the hard-up research man can get sufficiently well paid (for example, reviewing Ingle for DISCOVERY). The fifth item is the least obvious, but rather interesting. I added it recently when I had been going through my collection of reprints of the scientific papers of others, to discard those which I felt I could do without. At the end, I found to my surprise that my reject pile contained a high proportion of papers which had been delivered by invitation to some conference or symposium. I looked at them again. Many were by highly gifted authors on subjects of great interest to me. I still did not want them. The proportion of invited papers in my non-reject pile was small.

The clue probably lies in the recipe which one tends to follow for putting together an invited paper for a special occasion. The recipe is hash and waffle. By "hash" I really mean *re*-hash of results which have in the main already been published somewhere else. The concoction can be diverting and informative for one's listeners. But it seems that hash and waffle is a dish that does not keep.

This is not to suggest that published symposia and colloquia are not of immense value for the advance of science. Quite the contrary: the explosive expansion today of almost every sector of the scientific front makes a vital necessity of any and every means of keeping scientific workers in touch with each other, and with the latest advances in their own and neighbouring fields. The scientist who helps to perform this service richly deserves the gratitude and admiration of his fellows. But let him not think that he thereby necessarily makes an original and lasting contribution to knowledge. If *this* happens to be his ambition, there can be no compromise. He must be prepared ruthlessly to disembarrass his thoughts and his time-tables from every preoccupation other than his central quest.

CHAP ROTATION

I once worked in an applied research outfit which, among other peculiar practices, operated a sort of rotation of crops, or, rather, rotation of chaps. Once in every while—I do not now recall whether it was once in six or seven or eight weeks—each man was banished to a small room for a week, in which his only duty was to sit and muse. No one asked at the end of the week, "Did you have any bright ideas?" for this in itself might damp the muse. He was only asked to abstain from all routine work during that week. In exchange, the exile had arbitrary powers to commandeer any of the outfit's equipment or labour force if he wished to test his latest bright idea.

Some heads of research teams may look askance at this scheme. To those who are tempted to try it in their lab, I should emphasise the following. It must be made very clear that the exile who spends an apparently barren week with his feet on the table reading the comics gains the same merit in the eyes of the team and its leader as the one who emerges to suggest six new experiments and a modification of the Second Law of Thermodynamics. Otherwise the whole point is lost.

BROWSING

The rotation of chaps is only one of many possible devices for recharging the research man's mental batteries. The necessity of recharging is eloquently stated by Kursanov, employing a different metaphor: "A scientist is not a balloon, to reach a certain height and remain there for a long while on account of the material it was once filled with. He is 'heavier than air', more like an aeroplane, which has to keep going to maintain height or climb." It is well known that height is on average not maintained. Beveridge cites Lehman's figures for output at different ages. Taking the decade of life 30–39 as 100, the output for the years 20–29 was 30%–40%; for 40–49, 75%; for 50–59, about 30%. Assuming that the slow start is due to lack of knowledge and experience, is the later decline entirely due to biological ageing? I think not. Two features of a young scientist's life at once occur to me which tend to disappear with time and which may be important. One is browsing and the other is fairly frequent change of work and surroundings.

What senior scientist can be found sitting all day in the library looking through research periodicals because he has nothing else particular to do? And what research student does not from time to time do just this? As for change of work, Beveridge mentions the case of Ostwald, who successfully rejuvenated his mind by this means when he was over fifty years of age. In this connexion a proposal made by Kursanov's countryman, the nuclear physicist Peter Kapitsa, deserves attention. Kapitsa intends his suggestion for adoption in Russia, but there seems no obvious reason why it should not be applied more widely.

COMBAT FORCES

His idea is the setting up of *ad hoc* "mobile combat forces", each to be regarded "not as a permanent institution but as one set up to tackle a given problem over a period of months or years". Such a force would consist of scientists drawn from a number of different specialities, each with some special angle on the problem to be solved. After the successful solution of the problem, the combat force would be dissolved and its members would return to the permanent departments or institutes from which they had been recruited, or some of them might join new combat forces.

Something like this in fact occurred in Britain during the war, but with a measure of compulsion inadmissible in peacetime. Apart from the gain in efficiency, I see a valuable psychological advantage in such a scheme. It would enable even the senior research man to reverse his trend towards stagnation, for the scientific mind is more like a medicine than a wine: it should be well shaken before use.

Many readers will have other, and better suggestions than those which have been aired here. But enough, I think, has been said to show how many and how inviting are the paths in which Ingle has failed to tread.

GEOPHYSICS AND SPACE RESEARCH

By ANGELA CROOME

TABLE OF MAN-MADE OBJECTS CURRENTLY IN ORBIT

NAME					INITIAL ORBIT						RADIO		
General	*Astronomical*	*Up*	*Lifetime*	*Shape and Size*	*Period*	*Distance away*	*Angle to Equator*	*Weight*	*Instrumentation*	*Principal Scientific Value*	*Characteristics*	*Radio Lifetime*	*Other Points*
Explorer I (rocket and instrumented nose-cone)	1958 α	Feb. 1, 1958	4 years	Cone-nosed Tube, 80 × 6 in.	114·8 mins	219 to 1587 miles	33·2°	30·8 lb. payload 10-lb.	2 Geiger counters, Micrometeorite impactor	Discovery of Van Allen radiation	108 Mc/s (high power) 108·03 Mc/s (low power)	2½ weeks 3 months	Intensity of radiation jammed the signal
Vanguard I (instrumented sphere)	1958 β2	Mar. 17, 1958	100 years	Sphere 6·4 in. diam.	134·2 mins	404 to 2466 miles	34·3°	3¼ lb.	Inside and outside temperature difference	Testing solar batteries Geodetic studies	108 Mc/s (high power) 108·03 Mc/s on solar cells	2 weeks Indefinitely when sunlit	Sun-operated radio may last for centuries
Vanguard I (rocket)	1958 β1	Mar. 17, 1958	100 years	Tube, 48 × 20 in.	134·2 mins	404 to 2466 miles	34·3°	50 lb.	—		—	—	—
Sputnik III (instrumented nose-cone)	1958 δ2	May 15, 1958	19 months	Cone, 11·7 × 5·6 ft.	106 mins	140 to 1160 miles	65·2°	2926 lb.	9 instruments for studying the radiation, electric and magnetic properties of the Earth's environment	Probing of current systems above ionosphere. Quantitative and qualititative measurement of upper atmospheric gas	20·005 Mc/s (tracking and telemetry)	Indefinitely	Solar and chemical batteries are so arranged to give continuous transmission
Explorer IV (rocket and instrumented nose-cone)	1958 ε	July 26, 1958	13 months	Tube, 80 × 6 in.	110·18 mins	174 to 1365 miles	50° (launched in northerly direction)	38·5 lb.	Counters for refined study of Van Allen radiation	Refined study of Van Allen radiation and of artificial radiation from A-bomb tests	108 Mc/s (high power) 108·03 Mc/s (low power)	Some weeks 2 months (failed Sept. 19)	
Lunik (rocket and instrumented nose-cone)	Artificial Planet 1	Jan. 2, 1959	Indefinitely	Cone-nosed Tube ?	450 days (round sun)	91,000,000 (Jan. 14) to 122,000,000 miles (Sept.) —from Sun	Passed within 3700 miles of moon	3245 lb. 797 lb. payload	9 experiments to follow-up *Sputnik III* observations and relate them to conditions in space		19·993 Mc/s 19·995–19·997 Mc/s 183·6 Mc/s	? 62 hours	Telemetry Tracking
Vanguard II (instrumented sphere)	1959 α1	Feb. 17, 1959	50 years	Sphere, 20-in. diam.	126 mins	335 to 2300 miles	33°	21 lb.	Photo-cell recording equatorial cloud-cover	Weather forecasting	108 Mc/s (tracking) 108·03 Mc/s (telemetry of tape-recorded data)	4 weeks 18 days (ceased Mar. 7)	152 successful interrogations out of 211 circuits possible
Vanguard II (rocket)	1959 α2	Feb. 17, 1959	50 years	Tube, 48 × 20 in.	130 mins	335 to 2050 miles	33°	50 lb.	Painted to facilitate visual tracking	—	—	—	—
Pioneer IV (instrumented nose-cone)	Artificial Planet 2	Mar. 3, 1959	Indefinitely	Cone, 20 × 9 in.	392 days (round Sun)	91,700,000 (Mar. 17) to 102,400,000 miles (Oct. 1) —from Sun	Passed within 37,000 miles of moon	13·4 lb.	2 Geiger counters differently scaled; photo-cell; de-spin device	Van Allen radiation's penetrability, and extension into space	960·05 Mc/s (tracking and telemetry)	82·4 hours	Contact lost at 407,000 miles from Earth
Discoverer II (rocket and 2 instrument packs)	1959 β	Apr. 13, 1959	1 month	Cone-nosed Tube 19 ft. long	94 mins	156 to 243 miles	90° approx.	1600 lb. payload 440 lb.	Cosmic-ray emulsions; guidance and recovery apparatus	Technique for interception of ejected capsule			

Note: *Pioneer I* (Oct. 11–12), *Pioneer III* (Dec. 6–7), *Atlas* (Dec. 18–Jan. 21), possibly *Discoverer I* launched (Feb. 28) briefly achieved orbit since we published the last of these tables in September. *Discoverer I*, if successful, was the first space-vehicle to be launched into a pole-to-pole orbit.

Postscript: *Pioneer IV*'s Findings

In a preliminary account of the findings from *Pioneer IV*, the United States' third successful space probe launched towards the Moon on March 3 and now assumed to be in a 392-day orbit round the Sun, Prof. James Van Allen, speaking in Pasadena on March 20, gave the following facts. Basically the probe has given additional information on two aspects of the radiation surrounding the Earth, the extent of it in space and the relative intensity of the two regions.

Records from *Pioneer IV* show that the outer region of the radiation extends considerably farther out from the Earth than the data from the *Explorers* and *Pioneer III* had indicated. The lower limit of the outer zone was found to be the same as for *Pioneer III*, 8000 miles above the Earth's surface at the Equator, but the outer limit of the region was not reached until the probe had travelled 55,000 miles from the Earth (or approximately 14 earth-radii). This is a spectacular increase on the 12,000-mile outer limit estimated from the previous data. If these values are confirmed it will show that the Earth's magnetic field is still operative at 14 earth-radii.

Prof. Van Allen also indicated that the characteristic energy of the particles that predominate in the two zones varies widely, suggesting that the distribution of protons and electrons in the two zones is different and the origin of the radiation in each zone likewise different. This finding had been foreshadowed, not least in the papers discussing the data collected by the Russian space probe which appeared in the first two weeks of March. Prof. Van Allen described the inner radiation zone (lying approximately between 1400 and 3400 miles above the equator) as "by far the more deadly" and indicated that "heavy shielding" would be required for a man to pass safely through it. No figures are yet available but the statement suggests there is a high level of protons in the inner zone.

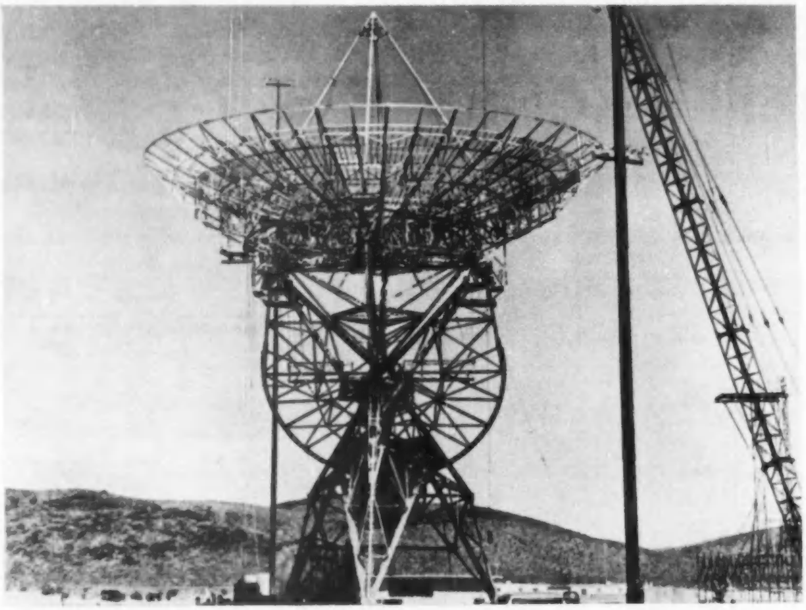


FIG. 1. The Goldstone Tracking Station which has an 85-ft.-diameter antenna. Built on the California desert by the Jet Propulsion Laboratory, the station tracks and receives telemetry from American moon probes.
(Reproduced by courtesy of Spaceflight*)*

New Maps of the Moon

Working rather over a century ago with only a 3¾-in. refractor telescope, Beer and Mädler's studies of the Moon's surface, through their completeness, brought Moon-mapping to a standstill for a hundred years. But now professional astronomers' interest in the Moon has been reawakened, various new lunar-mapping projects are afoot and one is already complete. The principal interest of each of these studies is distinct, so it is not surprising that the techniques employed are also different.

The "geological" map of the Moon to a scale of 1 : 1,500,000 now ready, has been prepared by the Russian geologist Alexander Khabakov and is designed to show by the use of various colours the estimated relative ages of the different lunar features. It draws on results made over long periods of study at the Pulkovo and Abastumani observatories. Khabakov leaves the processes by which the sequence of building events on the Moon came about an open question, and therefore the absolute ages of the different features. (A volcanic origin for the craters would require 150–200 million years as the total building period; if the Moon's principal features are attributed to meteoritic impact a very much longer period is necessary.)

The 12-year-long topographical project of the U.S. Naval observatory which is now nearing completion is designed to reduce navigational errors that have arisen when the Moon's rim has been used as a reference point in space. The project under the direction of Dr Chester Watts has concentrated on re-mapping the 19% of the lunar disc which is formed by the so-called marginal zone or outer rim. The peaks, valleys and plateaux of this region have been photographed when they were outlined against the sky. In all some 450,000 elevations have been measured. The photographic data is reduced to the form of a geodetic contour map in the final chart. The finished map is expected to reduce to only one-tenth of a mile the present errors of up to a quarter of a mile in recorded rim elevations.

The third Moon-mapping project is that being undertaken by a team led by Dr Gilbert Fielder of Manchester University using the 24-in. refractor at the Pic-du-Midi, and financed by the U.S. Air Force. This research will take five years to produce a map of the whole of the disc turned towards the Earth; the error in the elevations is expected to be only 50 to 80 ft. and distances should be accurate to half a mile.

The survey will be done by taking sequences of photographs at intervals of half a minute or a minute of those parts of the Moon on which the Sun is just rising or setting. The low angle of the Sun shows up the topography of the Moon's surface in the pattern of shadows cast. The lengths of the shadows are then measured on the photograph, and the surface calculated by triangulation.

Biology's Place in Antarctic Studies

Perhaps the most interesting feature of the third meeting of SCAR (Special Committee for Antarctic Research), which took place at Canberra, March 2–6, was the presentation of the report of the working group on biological studies in the Antarctic. Considering that the main IGY effort has been concentrated on physical research, SCAR recommended that national committees give adequate consideration to the importance of biological investigations.

The fields of study of special interest are outlined in the report. They are divided under two main headings, oceanographic biology and "Terrestrial Biology and Medical Research", which embraces all forms of life to be found on the Antarctic continent from microbes to man. It is worth noting the emphasis put on the need to pursue physical and biological studies side by side "because interpretation of the latter depends on the former and both require the same expensive facility, a research vessel".

Here are some recommendations:

"The Antarctic offers unique opportunities for biological research, much of which is closely related to the human occupation of this region. Man's physical and biological impact on the endemic Antarctic animals, plants, and microbes is still slight, but this undisturbed situation will soon pass as the isolation of this region from the rest of the world is reduced.

"The severe environment has led to high physiological adaptation and relative ecological simplicity, the understanding of which sheds light on conditions elsewhere.

"Biogeographical problems in the southern hemisphere require circumpolar study of the distribution of flora and fauna. This should extend as far from the Antarctic continent as is necessary to establish the biological relations between Antarctica and other land masses."

Investigations of the effects of cold and photoperiodism on man and in the highly specialised fauna of the Antarctic regions are recommended in the physiological field. Among behaviour studies, that of the psychology of isolated groups of men is proposed.

In microbiology, a survey is required of diseases already present in Antarctica's isolated and semi-isolated fauna, and of their potential threat to man. For, in medical and animal microbiology, unique opportunities exist in Antarctica for studying man's impact upon a relatively uncontaminated environment. Also of interest is the survival of bacteria brought in from outside (for example, colds on relief ships) under polar conditions.

FIG. 2. (*Right*), some of the experimental instruments of *Vanguard* Satellite Launching Vehicle 5. (*Left*), the *Vanguard IIIA* sphere containing a magnetometer to measure the Earth's magnetic field. (*Right*), the *Vanguard IIIB* 30-in. plastic and aluminium foil sphere which measures drag in space caused by gases and particles. (*Centre*), the sphere folded into the dish which is attached beneath the *Vanguard IIIA* sphere for the launch.

FIG. 3 (*below*). A helicopter takes off from the *Soya*, the Japanese Antarctic expedition ship, to take supplies to the expedition party on Ongul Island. The *Soya* returned to Tokyo after a 152-day trip and brought back 30 tons of Ongul Island rock for analysis.

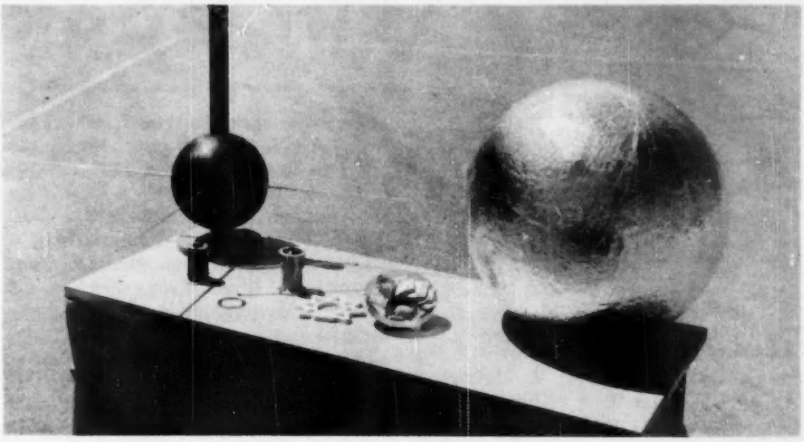
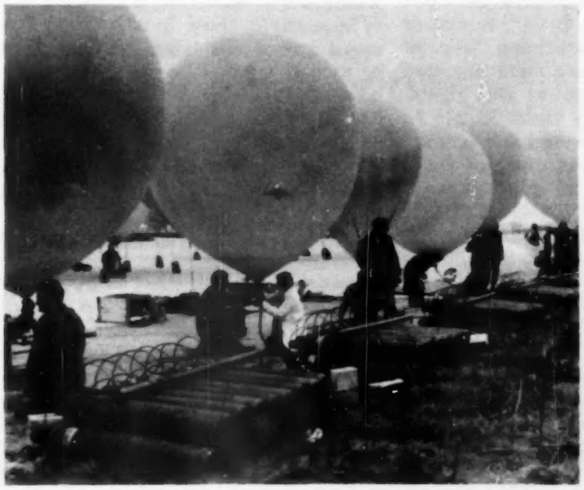
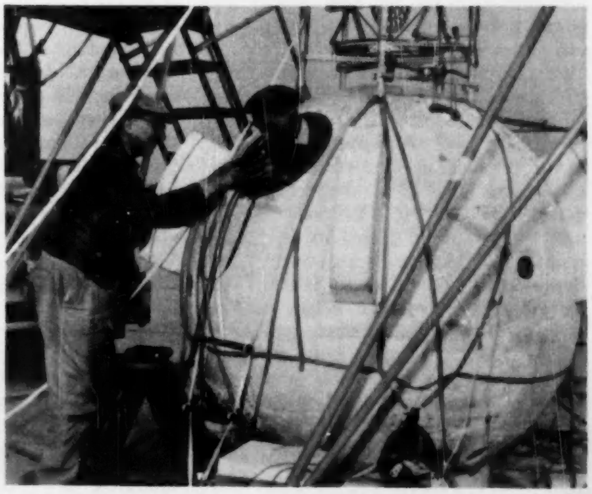


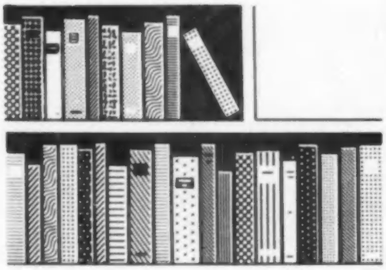
FIG. 4 (*below*). At the end of April, Audoin Dollfus, a French astronomer, ascended to the height of 12,800 m. (about 42,000 ft.) in a pressurised gondola towed by 100 hydrogen balloons. The gondola is equipped with telescopes and on future ascents he will study Venus and its surrounding atmosphere. The hydrogen balloons are inflated before the ascent which took place at Villacoublay (France).

FIG. 5 (*above*). Members of the Japanese Antarctic expedition checking weather reports in their hut on Ongul Island. They will remain on the ice-bound island until 1960.

FIG. 6 (*below*). Audoin Dollfus in the gondola just before the ascent.







THE BOOKSHELF

A History of Technology, Vol. V

Edited by C. Singer, E. J. Holmyard, A. R. Hall, and T. I. Williams. "The Late 19th century *c.* 1850–*c.* 1900." (*Clarendon Press; Oxford University Press, 1958, xxxviii+888 pp., 44 plates, 415 figures in the text, and 23 tail-pieces. £8 8s.*)

A reader born, as was the reviewer, almost literally at the turn of the century, approaches this concluding volume of the series with feelings of a kind quite different from those—largely academic—which were awakened by study of the preceding volumes. For it is the genesis of his own world which he will see unfolding; and for the reviewer, the enormously enlarged knowledge which he has thus acquired has strengthened his previous prejudice that there is a great deal too much loose talk about the huge acceleration of technological change during the present century. Of greatly increased sociological impact due to the expansion of production and distribution, the present century has indeed been a witness on an unparalleled scale. But apart from much more rapid long-distance communication (a sudden impulse to travel from the centre of Birmingham to the centre of London could have been more quickly realised fifty years ago than today) technological novelty has been less marked in the last half-century than in the previous one. To one's fifty-year-old memories of the more obvious "modern" amenities, for example, electric light, motor transport, telephones, cinemas, gramophones, are added from these pages such less familiar innovations of the 19th century as vacuum condensed and dried milk (50s); dried egg (70s); petrol cracking (90s); domestic lighting and local railway driven by hydroelectricity (80s); duplex telegraphy ('54, but undeveloped for twenty years); submarines ('89); synthetic drugs, such as aspirin, phenacetin, veronal, established before 1900; 60 m.p.h. train speeds, a commonplace on the GWR in the 60s; rotary press and Linotype; London traffic so congested by the 50s that relief had to be sought by means of the underground (1863) and the "electric tube" before 1900; compressed-air riveter ('65); effective gliding in the 90s; photographic survey ('58); iron frame and glass building ('55); electric safety lift ('89); mass-produced small arms ammunition (70s). Equally impressive are the indications of the coming pattern of rationalisation and organisation. It comes as a shock to discover that patent-pooling, instalment purchase, and sales-and-service are all over a century old; yet all these, and almost all revolutionary innovations in dozens of widely different industries, were the accompaniment of the exploitation of the sewing-machine, which "effectively ended the traditional bondage of women to the needle".

The editors rightly stress that "the importance of applied science is the outstanding theme of this volume". Obvious in the chemical and electrical industries, it came to be of critical importance in ship design (1869, Froude's experiments with models in a tank); building construction (Rankine's textbook); turbulent and streamlined flow (Osborne Reynolds); plantation rubber seedlings (reared at Kew, acclimatised and distributed by the Royal Botanic Gardens of Ceylon and Malaya); and explosives (Nobel's critical work on the conditions of stability of nitrocellulose). Of special interest to the historian of the methodology of science is the light shed by Prof. J. Allen on the growing relationship between mathematical theory, experiment, and empirical practice in (hydraulic) engineering: "Characteristic of 19th-century progress is the development of realistic formulae based on observations, together with theories that partially explained the facts as observed and that provided some basis for extrapolation of generalisation" (p. 546). The corollary to this invasion of the kingdom of the "arts" and "inspired guess-work" by "science" was the need for scientific education at the highest level. How lamentably Great Britain (it won't do to lay the blame solely on "the Government": there was a lack of vision among the "leaders" of industry) failed to rise to the challenge is told by Sir Eric Ashby. How incomplete, though in many ways so admirable, has been the ultimate response is indicated by Sir Eric's comment (p. 793): "It is ironical that today, three generations later, these recommendations [*sc.* of the Royal Commission on Scientific Instruction, etc., 1875] would be regarded as too drastic for most British schools." How frequently Government has gravely handicapped progress is shown by the effect of excessive road tolls (p. 420) and restrictive legislation (p. 429) on the development of mechanically propelled vehicles; the famous "taxes on knowledge" (paper, newspaper, and advertisements p. 699); and lack of interest in the Kynoch small arms cartridge. Progress was nearly always brought about by determined individuals: Gilchrist Thomas (whose paper was rejected by the British Iron and Steel Institute, p. 60) and Hancock (Ch. 31 *passim*) come to mind.

But there is no room for more; though not the half has been said which at the most modest reckoning ought to have been said. The "conclusion of the matter" is admirably put by an economic historian, Charles Wilson, and by one who, had he been born fifty years earlier, would have been among the heroes depicted in these pages.

The fate of those who have done something extremely well is always to be asked to do something more. From one who has had the privilege of enlarging his mind by reviewing the last three volumes of this co-operative masterpiece at no expense to himself comes the final plea on behalf of his less fortunate colleagues—could not these great benefactors, Imperial Chemical Industries, contrive with their collaborators—authors and Press—to re-issue in due season some form of abridgement whereby this treasure house might be more widely owned?

W. P. D. WIGHTMAN

Looking and Finding

By G. Grigson (*London, Phoenix House, 1958, 120 pp., 9s. 6d.*)

This book, intended for young people, deals with many things, from maps to weathercocks, which one can see and find in town and country. It tells only a little about a particular thing, but at the end of each chapter there is a list of books where one can find more about each item. The book tries to make us find out and be more interested in everything around us; for instance, I saw some strange letters on a house for the first time after reading the book, although I had seen the house before. As a girl of twelve, I would recommend this book to other children in general, although some might not get further than the end of the first chapter. Grown-ups, interested in children's books, might also like to read it. The drawings by C. Chamberlain are pleasing to look at, particularly the frontispiece, which is, I think, exactly like a second-hand bookshop I once saw.

P. SAINSBURY

"The Admiralty Regrets . . ."

By C. E. T. Warren and J. Benson (*G. G. Harrap & Co., 1958, 224 pp., 15 plates, 3 maps and diagrams, 17s. 6d. net*)

Could the *Thetis* have been saved? In their book, "The Admiralty Regrets", the authors give a detailed and dramatic account of the loss of the submarine *Thetis*, which sank in 1939 on her trial trip, with a loss of ninety-nine lives. The immediate cause of the sinking was the opening of the bow cap of one of the torpedo-tubes at some undetermined time before the trial and the subsequent opening, under a misapprehension, of the rear door of the same tube. The sea flooded into the two foremost compartments and the submarine sank. During the rescue operations the stern was actually lifted out of the water: the photographs of the stern showing above the waves, with the small rescue boats standing impotently by, is one of the tragic features of the book.

The authors do not hesitate to point out where in their opinion the rescue work was unnecessarily delayed and the various factors—the general uncertainty, the lack of positive urgent direction—that wasted the vital hours before rescue was attempted.

Could the officers and crew of the *Thetis* have brought her to the surface by their own ingenuity? The theory was put forward some years ago in a novel dealing with the submarine service, that by changing over internal piping so that the hydraulic power system could operate in reverse, it would have been possible to shut the bow cap of the torpedo-tube and thus allow the flooded compartments to be pumped out. The fact that the other bow caps would open would be of no consequence, as the rear doors of the other tubes were all shut. The authors of this book do not mention this theory, and it is not within the competence of a layman to discuss it. After all, in addition to the naval officers on board who had grown up in the service there were the experts of the shipbuilders, and it is difficult to conceive that their united brains should not have produced such an idea if it were feasible.

The many who remember the *Thetis* tragedy, and newcomers to the naval scientific service, will read this book with regretful interest, and for the civilian it is an exciting story told with a restraint that makes it all the more poignant.

G. PARR

The Decipherment of Linear B

By John Chadwick (*Cambridge University Press, 1958, 147 pp., 18s. 6d.*)

It appears that the firing of a pot or the burning of a palace may preserve ephemeral inscriptions. In Pylos, Knossos, and Mycenae, clay was burnt, palaces fell in ruin, but the little notes on the clay remained to be discovered by archaeologists.

John Chadwick worked with Michael Ventris through all the later stages of the decipherment of the Mycenean script which is known as Linear B. He tells the story well, of the mathematical analyses of symbols, the slow selection of certain forms as grammatical structures, the first identification of place-names. At that point the work must go forward. Before it no word could be given sound, it consisted only of visual symbols almost certainly representing syllables. After that some symbols became sound, and when applied to words it became curiously Greek. Ventris had struggled firmly against this Greek hypothesis until it convinced him. Everything had been done on a very sane consideration of probabilities, and with a leaning towards Etruscan as the closest probable relative to the language expected. It did not work out that way: the determinative symbols, where they could be clearly recognised, paralleled words in the text which were in a curious Greek, much like the philologists' idea of what an early form of the language should be.

One can have no remaining doubt that the language last spoken in Knossos was Greek, and that language as well as culture was shared by the cities of Achaean Greece.

The syllabary is not extensive, about ninety symbols in all, and some of these can be used for sounds which are not exactly identical. It is a halting and clumsy vehicle for expression, but efficient enough for keeping the simple records of tribute and equipment which constitute the matter of the tablets deciphered. It forms a normal step in the development of phonetic writing. It seems to have been the secret of a quite limited class of recorders, and perhaps of chiefs. Its limitation in practical use seems to have been as great as the limitation of runes within the culture of the Viking period. What was written on paper or skin is irrevocably lost. All we have is a confused echo of the sounds of that distant world in the poems of Homer.

The decipherment of the script opens a new way into the past of European history. This world of Mycenean culture was ancestral to so much of what we all hold as a European heritage. What went before may be hinted at when the Linear A script of Crete, already obviously a different linguistic strain, comes to be read.

One finds in Mr Chadwick's book a very readable account of the discoveries which are opening for us a first small, sharp contact with the mind of men in Europe three and a half millennia ago.

C. A. BURLAND

The Rose in Britain

By N. P. Harvey (*Souvenir Press, London, and Ryerson Press, Toronto, xii+244 pp., 23 colour-plates and 3 diagrams, 25s.*)

This is the fourth edition, completely revised, of this "enlightened modern treatise". The book is thoroughly pleasing to the eye, with a handsome dust-jacket, elegant binding, clearly printed on good paper, and contains no less than 23 five-colour plates each of full-page size. Many of these are extremely good, though some lack design and others appear rather flat. The author gives us an insight to many of the other ramifications of the rose, and writes in a fresh manner, bringing numerous references to music, food, wine, etc., to bear in his desire to give us all his wide fund of knowledge on the subject. Besides these very personal asides and correlations he also gives us quotations, very apt, and sometimes amusing, from the views of writers through the long pages of history.

There is a brief chapter on history and one of particular interest on scent. Pests, diseases, and propagation are dealt with concisely and well. Hybrid teas, floribundas, and climbers are each given chapters, which cover all the usual points and many others. There are many helpful lists of varieties in both categories to guide our choice. Nearly half the book of 212 pages is given to his Glossary, in which he discusses the merits and disadvantages of over 300 varieties in a personal way. They are nearly all hybrid teas and floribundas but include a scattering of old and new favourites among the shrub roses. It is up-to-the-minute information of an original kind, and the strange new "off" colours of "Gletscher", "Royal Tan", and "Café", find favour with Mr Harvey. Some of his statements I find rather sweeping, and cannot quite understand how (cf. "Frau Karl Druschki"), if a rose is very vigorous and resents hard pruning it can be considered suitable for a standard, a form of growing the author traditionally pursues. Nor can I connect "Breeze Hill" with "Gloire de Dijon". But these are small points. There is an index, and many lists of references to aid further search for knowledge. It is a concise and pleasant book for the modern rose-lover.

G. S. THOMAS

The Sleepwalkers

By Arthur Koestler (*Hutchinson, 1959, 25s.*)

There are many refreshing signs that the study of the history of science is at last turning away from the "deciphering-the-

tombstone" and "who-discovered-it-first" attitudes. The proper history of any subject should be much more than a chronology and should include the relation of men's ideas and work not only to the age and society in which they live but also to their own experiences and beliefs, lives, and personalities.

In this book—that of "men's changing ideas about the universe"—Koestler is more concerned with the men who changed the ideas rather than the ideas themselves. Making available for the first time in English translation hitherto unfamiliar material about Kepler, he gives a brilliant picture of him as a man, as well as a scientist, showing how false and unnecessary this distinction is. He shows, too, how the motives that led Kepler, Tycho Brahe, Copernicus, and Galileo to do the work they did and arrive at those conclusions which effected what is loosely called "The Copernican Revolution", were not motives to which the word "scientific" is usually applied. Moreover, Koestler has read and studied the original sources and reveals again what becomes more and more apparent in the history of science, how much of our misinterpretation has been due to second- or third-hand source material.

While Koestler is talking about men he is excellent; when he is talking about science and ideas he is often extremely weak. The section on Greek science is especially poor, and one is sorry to see that in his list of references he does not include Sambursky's work, "The Physical World of the Greeks". Koestler tries to represent the failure of the Greeks to accept the earliest heliocentric theories as a mixture of "failure of nerve", a desire to "save the appearances"; a desire which Koestler implies is misguided. He fails to show how forceful and scientific was the evidence against the possibility of a moving earth and how the Greeks would have been flying in the face of scientific reason had they in fact ignored it. This evidence was mostly derived from the study of movement. It is in his analysis of the problems of dynamics and their relation to theories of the heavens that he is weakest, not only when discussing the problems that faced the Greeks but those that faced Galileo and Newton also.

It is sad that, in a book that in many ways is both excellent and fascinating, Koestler falls into the error of dismissing other people's "failures", or attempts, in a patronising and superior manner. From the safe distance of two thousand years one can, if one wishes, talk of Eudoxus's system as being "dishonest", Plato's as being "profoundly distasteful", and other systems as being "mad". But these models and systems did the jobs that they were meant to do and were sensible in terms of their times. If they didn't explain everything, or seemed compounded of certain "oddities", that, at least, is something that they share with many of our contemporary scientific ideas.

J. GOODFIELD

The Development of Iron and Steel Technology in China

By Joseph Needham, SC.D., F.R.S. (*London, The Newcomen Society for the Study of the History of Engineering and Technology, The Science Museum, 76 pp., 55s.*)

The Second Biennial Dickinson Memorial Lecture, originally delivered to the Newcomen Society in 1956 by Dr Needham, has now been published in book form. The material of the lecture will, moreover, eventually form part of the fourth volume of "Science and Civilisation in China", now in course of publication in seven volumes by the Cambridge University Press. The author traces, in a well-documented treatise, the history of iron and steel production in ancient and medieval China and shows how, in developing its technology, China seems to have taken a course radically different from that of Indian, Islamic, and European cultures. The unusual characteristic of early iron production in China was the abundance, from about 300 B.C. onwards, of true liquid cast iron, for the Chinese discovered how to melt iron almost as soon as it was known. This is in sharpest contrast with the course of events in other parts of the Old World, where some 2½ millennia passed between the first iron-working and the first casting of iron, in about the 14th century. Moreover, it was the Chinese, not the Europeans, who could make steel by advanced methods, quite unknown to the Western world until a much later date, though probably the tonnages produced remained extremely small. The Chinese first found a way, in about 100 B.C., of obtaining steel directly from cast iron by the discreet use of the oxidising blast.

In about A.D. 400, they discovered that by combining cast with wrought iron in the co-fusion method, or a "visco-liquid diffusion process", still more steel could be produced. This was an extraordinary invention, considering that men in those days knew absolutely nothing about the chemistry of iron-making.

The plates accompanying the text are useful, as are many of the contemporary accounts of iron- and steel-making; some of these accounts have been translated for the first time.

It is also interesting to see that the designs of many of the ancient methods of iron and steel manufacture are very similar, with certain modifications, to the small-scale production units which have come into prominence in the 1958 "big leap forward" in iron and steel production in China. These include the small blast furnace with its double-acting-piston bellows and the refining hearth for decarburisation of steel.

D. H. RIPPON

A Baby is Born

(*New York, 1957, The Maternity Center Association, $6*)

This is a book 11¼ × 8¼ in., lavishly illustrated with full-page photographs to show lay people what happens during labour. The anatomy of the female and male bodies is described and the changes in pregnancy. There is a series of pictures showing vertex and a shorter series of breech delivery. Twinning is mentioned. The illustrations are of sculptures of a sagittal section of the pelvis and uterus. They show the organs half actual size.

My wife's criticism is that the pictures show the woman on her back throughout labour, an uncomfortable position and unnecessary except in the final stages. (It is, of course, adopted because it is "most convenient for the midwife and doctor".) My main criticism is of the method of binding by rings. One page was already adrift in the copy sent to me for review. The new-born baby should not have been shorn of the umbilical cord stump.

The text is given in English, French, and Spanish. This is a potentially very useful book; it is well done and is the more acceptable because it is well produced.

R. MAC KEITH

Principles of Statistical Techniques

By P. G. Moore (*Cambridge University Press, 1958, 239 pp., 22s. 6d.*)

This is an introductory textbook on statistics for schools, and for university students not specialising in mathematics.

The first half of the book deals with the collection and presentation of statistical data. Here the university student will probably find the treatment too elementary. The transition from one meaning of statistics to the other—that is, from the technique of quantitative description to the science of probability theory and sampling—is handled with remarkable smoothness, and this in itself is a valuable achievement. The reader who comes to statistics through this book may escape altogether the chronic neurosis of the professional statistician, who can never forget the radical ambiguity which splits his subject down the middle.

The second half of the book introduces probability and sampling and tests of significance. The classical approach to the normal distribution is followed: through the binomial theorem and the

binomial distribution. Tests of significance are given for the mean and the standard deviation, but only for the case where the population value of the standard deviation is known. Thus Student's t is not mentioned, and the only application of chi-squared quoted is for testing the standard deviation. This somewhat puritan restraint about significance tests represents the sacrifice of practical utility to logical coherence: to have expounded the more useful tests would have interrupted the flow of the argument.

The last three chapters are the best; they deal with index numbers, time series, and correlation.

The merit of the book is the smoothness of its logical development. The defect is that it makes statistics intolerably dull. An almost representative sample of the exercises at the end of Chapter 6 offers the reader the following thrilling tasks:

"Calculate the mean, median, and mode for the ages of American railroad male employees who were members of a retirement scheme in 1944. . . . Calculate the mean, median and mode for the number of bracts on specimens of wild carrot collected in Michigan. . . . The shoulder widths of 56 three-month-old infants are tabulated below. Calculate the mean, median and mode. . . . A group of 5000 drivers sustained the numbers of accidents given below. Calculate the mean and median. . . ."

Even to know whether they drove cars, buses, or steamrollers would be something.

C. S. O'D. SCOTT

Exercitationes duae Anatomicae de Circulatione Sanguinis

By William Harvey. Translated by K. V. Franklin (*Blackwell, 1958*)

Dr Chauvois has devoted many years to the study of Harvey's Latin texts, and his commentaries on these texts are well known. His book, "William Harvey: His Life and Times; His Discoveries; His Methods", was published in English and French in 1957. Dr Chauvois has now kindly agreed to comment on the second volume of Prof. K. J. Franklin's translations of Harvey's work.

Having just read the second volume in translation of the works of William Harvey ("Exercitationes duae Anatomicae de Circulatione Sanguinis" of 1649, with the addition of some Latin letters), your reviewer can only admire once again the beautiful work of presentation by the publishers.

As regards the talent shown by the translator, Prof. K. J. Franklin, it fully deserves a reiteration of the praises already showered upon it in 1957. I only wish to point out that the present translation is not limited to the "Exercitationes duae Anatomicae de Circulatione Sanguinis", the principal work, but that it contains in addition, at the beginning of the volume, the translation of a letter which Harvey, during a short stay with the Arundel Embassy in Nuremberg in 1636, wrote on May 20 to Caspar Hoffman, the celebrated Professor of Anatomy in the neighbouring University of Altdorf. As a staunch supporter of Galen and his doctrines, Hoffmann had made some rather violent statements against Harvey, who suggested a meeting in the lecture room before a corpse, with the object of proving his points. There is also the translation, after the "Exercitationes duae . . ." of some other Latin letters written by Harvey between March 1651 and April 1657 (the year of his death). The volume ends with some original Latin texts translated to allow comparison between the translation and the texts. Four additions in England (a preface, a short biography of Harvey, three pages of "Annotations on the two Anatomical Essays to Riolan", and an epilogue at the end of the volume), inserted by the translator himself, help to throw some light on the kind of subjects treated, and the circumstances of their appearance during Harvey's lifetime.

In this connexion your reviewer must express regret that the "Annotations" have not brought out the point of difference, in his opinion essential, between the "Exercitationes duae . . ." of 1649 and the "Exercitatio" of 1628, which makes them so interesting and so striking for us still today. Namely, Harvey's categorical assertion, *after twenty-one years of careful reflexion*, that one is not entitled when describing the circulation to start with the right auricle of the heart simply because this is "motory" and therefore supposedly sets the blood-stream in motion: an auxiliary motor along the way must not be confused with the *restorative sources* at the origin of the stream. This deplorable reasoning with regard to the "motory" heart, which is still responsible for our present formula, that old classical diagram: blood from the *right ventricle of the heart* is sent to the lungs, from the lungs to the left ventricle, from the left ventricle to the organs of the body, and so back to the ventricle again—is contradicted by two passages which Prof. K. J. Franklin has in fact translated so well:

Page 62, line 21 and the following: "But if by this term 'the heart' they understand the body of the heart with its ventricles and auricles only, I do not believe that it is the fabricator of the blood, nor does the blood have force, vigour, reason, movement, or heat as the gift of the heart."

Page 56, lines 34–35 and the following: "Because I see many held up and in doubt about the circulation, and . . ." and so forth.

All this being of a pressing actuality, your reviewer is certain that in a second edition, which must surely not be long delayed in view of the success which his fine translations are bound to have, Prof. Franklin will stress very clearly in his "Annotations" this characteristic, which makes the "Exercitationes duae . . ." something entirely new, and not, as has been so often and so rashly suggested by those who have not understood them, simply the tedious repetition of the 1628 "Exercitatio".

L. CHAUVOIS

Readings in the Life Sciences

A Selection of 52 articles that have appeared in Scientific American *since 1948.*

Scientific American is offering a new educational service whereby reprints of articles are supplied in quantity to teachers as supplementary course reading for their students. The reprints will present the articles exactly as they appeared in the magazine, with full illustration and colour. A list of 52 articles published in the past has been prepared, and teachers are invited to select those that fit their plan of instruction best. The assembled articles, in effect, furnish teacher and students with a tailor-made reader, covering current work in significant lines of research not yet represented in textbooks. The articles are written by scientists directly engaged in the work reported. The authors describe the process as well as the results of investigation.

Scientific American is undertaking this service in the life sciences only, for the time being. Reprints of articles in other fields can be made available if there is sufficient demand for them. The reprints are boxed as individual sets, and the applicant receives a complimentary copy of each reprint ordered.

Results of IGY

The British National Committee for the International Geophysical Year issued at the end of the IGY a most interesting booklet, called "Some International Geophysical Year Achievements"; the booklet is available from the Royal Society in London.

Prepared by the Committee, each of the fifteen subjects, into which the IGY activities were divided, are briefly reviewed and some of the results which have already been worked out are given. Naturally many months must elapse before all IGY research becomes available.

SCIENCE ON THE SCREEN

Science Television: Directed or Drifting?

It is accepted that the cultural excellence of the Third Programme has excited the admiration, indeed envy, of the whole broadcasting world. Since as yet we have no Third Programme on television, it is incumbent on certain classes of television programmes to maintain the established Third Programme tradition. Unless this is done we may never hope to see a television Third comparable to the sound Third. Already we have in television a clear nucleus indicating the necessary standard. One can certainly include, for instance, the Brains Trust, much of the high-quality drama and ballet we see, many distinguished solo musical performances, many economic, social, and political surveys, numerous psychological studies, and essentially many formal scientific broadcasts. The question will arise then, and indeed arises now: how much direction from above is required in administering cultural broadcasts?

The magnificent musical output on sound radio is due to the fact that the programmes are planned by practising musical experts. Indeed, to paraphrase Lincoln, there is direction of the musician by the musician for the musician. In consequence, an incredible number of people in this country have cultivated a fine taste in music and culture. One cannot emphasise enough that it is the direction, from above, not the "box office" of listeners, which has set the standard, and having maintained it has raised the level of taste.

Then again, one of our annual social artistic events is the Royal Academy Summer Exhibition of Painting and Sculpture. As many as 10,000 aspirants can submit their work. As is natural and right, the work is accepted or rejected by practising experts who can judge from first-hand experience. These experts become the arbiters of what the 50,000 or more visitors to the Royal Academy Exhibition will see. Of course there are those who disagree with some of what will be shown, for taste is a notoriously fickle mistress, but it is to be noted that the Royal Academy does not seek to *dictate* to the artist, its function is to *select*, and by doing so it hopes to guide public taste. The *avant-garde* may object, but if it has anything of real value to offer it need not worry, for in due course, after the necessary decent interval, the Academy will catch up.

The main point is that public appreciation of music and of the plastic arts tends to be directed by practising experts. But what of the cultivation of popular appreciation of scientific progress? The British Association for the Advancement of Science has, it is true, its annual show-piece to acquaint the public with scientific achievements, but one week a year of concentrated publicity is far from what is required. One cannot compare the British Association's influence on the spread of scientific knowledge with the influence of sound radio on the spread of knowledge about cultural matters.

Surely it must be recognised even by the most obstinate advocates of the humanities, that whether for good or evil, the most powerful force of our age is science and its technological repercussions. If this is accepted, then we may well ask, which is the corresponding body of expert scientists guiding science television broadcast policy? And the devastating reply is that neither BBC nor ITA have in the past had such a panel of practising scientists for guidance. There has been no real direction, just happy, haphazard drifting. Putting it in a nutshell, the TV science direction requires directing. Not that they require guidance in the practical techniques of production, there they are competent enough, but in the bigger outlook some help is needed. Certainly we have seen numerous excellent individual programmes, but the grand strategy is absent, and absent because there is no general staff.

What sort of general staff does your reviewer envisage? Well, it must be large and comprehensive, and should consist mainly of practising scientists, say four distinguished university scientists—physicist, chemist, biologist, and geologist. Add three important industrial scientists, perhaps a metal engineer, an electronics specialist, and a chemical engineer. Then add three members from some of the larger government research establishments such as the NPL, Harwell, and the Royal Aircraft Establishment. Finally, there should be a distinguished headmaster, a representative from the British Association, and perhaps the editor of a science journal, and we would have a formidable body of thirteen who could be trusted to produce a balanced science television policy for the nation. Implicit would be the basic recognition for adequate programme time and in this respect representations to both ITA as well as BBC would be desirable and equally important.

As to programme character, it is not enough only to entertain or even only to inform, admirable as both may be in their own right. Science television simply must go further than this. The ultimate aim should be to raise the general level of scientific knowledge. By all means let us still have science fantasies like "Journey into Space" on the sound and like "Quatermass" on television, but let us not confuse the issue by imagining that these are serious contributions. To compare such light amusements with fundamental science programmes is like comparing a Broadway musical with "Parsifal".

Any fears producers may have that they might lose some of their audiences are understandable but perhaps exaggerated. If the mass media have taught enormous numbers to appreciate obscure chamber music, they can equally persevere with serious science programmes. Adequate science broadcasting guided by practising scientists must be insisted upon, whether the audience thins out or not. If 60%, 70%, or even 80% of viewers switch to song and dance, then let them. The 20% who stay put are all the more worth cultivating and even if they are only 20% they may still well amount to the formidable figure of a million. The current crazy scramble in the broadcasting administration for peak viewing numbers is ignoble and disastrous and should be fiercely condemned. Not until this paralysing influence of viewer statistics is eradicated will television broadcasting become the cultural force it ought to be.

S. TOLANSKY

Zonation: 16 mm. Kodachrome, Sound, 16½ mins.

This film made by the Sydney Scientific Film Society in conjunction with the Australian Museum, the Zoology Department of the University of Sydney, and CSIRO sets out to show how different types of marine creatures living on rock platforms in the region between high and low tide limits take up positions in well-defined and easily recognisable zones.

The fauna of the inter-tidal zones of Eastern Australia is one of the richest and most densely populated in the world and perhaps this is the reason for the main fault of the film—too many animals are presented too quickly. Certainly the individual "shots" are always striking and often beautiful but the overall effect is to lose the avowed purpose of the film

which is to demonstrate and explain one of the basic facts of inter-tidal ecology. We are told in the commentary that zonation occurs but there is not one scene in the film which shows at a glance what exactly it is. A diagram, one feels, is needed or, if a diagram is considered too intrusive, a view of the inter-tidal region of a near-vertical rock face where the indicator animals of the zones occupy a band of about 7 ft.—a distance easily scanned by the camera so that the animals remain distinguishable. Without some such aid it is hard, even for the specialist, immediately to place the animals presented in proper perspective.

Lay members of the audience will find a difficulty with most of the animals being called by their zoological names, but since very few of them have common names the difficulty is inherent. Perhaps this does not really matter and the layman, together with the more specialised audience, may well be satisfied with the excellent photography of a considerable number of little known, striking and sometimes exotic marine fauna.

J. SIMONS

Establishment of an International Film and Television Council

The delegates of twenty-four international film and television organisations met at UNESCO House during October 1958.

They decided to bring into being an International Film and Television Council which, while fully preserving the autonomy of the various international associations concerned, could ensure co-operation between its members and work towards the co-ordination of their activities.

An Executive Board was elected which drafted a programme of activities which was presented to an Extraordinary General Assembly of the Council to be convened at the beginning of the year.

Mr John Maddison was elected President of the International Film and Television Council, and the nomination of M. Jean Benoit-Levy as Delegate-General of the new organisation was ratified.

Film Vocabulary

Prepared by Cinema Sub-Committee of Western European Union. *(London: H.M. Stationery Office 12s. 6d.) 1958.*

Some 900 terms in current use for the production, distribution, and presentation of teaching and cultural films are presented in French, English, Dutch, Italian, and German. The French section is arranged in a concurrent alphabetical and numerical order. The same words will be found in the other languages, first in numerical order (according to the French version) and then in alphabetical order. A number of very useful conversion tables have been printed at the end of this most practical and praiseworthy international pocket-book.

C. E. ENGEL

LETTER TO THE EDITOR

The History of the Phytotron

Sir:

An interesting account of the new Australian phytotron, which is being built at Canberra, appeared in the February issue of DISCOVERY. It was stated that the design of the installation was radically new, consisting of a large number (about 300) of independent units; nevertheless, although there exists no other large-scale phytotron using this type of equipment, its basic design is not new.

In fact a set of twelve similar controlled and independent plant growth chambers has been in use in our laboratory at Rothamsted since 1954 and their design served largely as a model on which the Australian plans were based.

The engineer and designer of the Canberra installation visited this country and inspected our equipment, and they have acknowledged that their ultimate design was influenced to a considerable extent by ours.

Attempts to grow plants in completely controlled environments have a long history. However, the first large-scale installation of this kind at the Boyce Thompson Institute for Plant Research did not come into use until 1924, and the Earhart Laboratory in California was erected in 1949. The latter, which gave rise to the name phytotron, was designed by Prof. Went specifically for the study of the effects of all factors of the physical environment on plant growth. Its construction represents a combination of air-conditioned glasshouses which have a greater or lesser degree of temperature control, and growth rooms in which not only temperature, but humidity and illumination intensity and duration also, are fully controlled. Plants are usually grown on trolleys which can be moved as desired from one environment to another. Similar phytotrons are now in use or being built in France (Gif-sur-Yvette), Holland (Wageningen), and Belgium (Liége).

Equipment without glasshouses (usually in smaller installations) also aims at complete control of the environment. In such controlled rooms it is difficult to obtain the high light intensities needed for optimum growth, and even in the best of them the spectral composition of the light, though largely constant, cannot be varied at will; nor is it identical with that of daylight. None of the light sources available allow for such control and with many of them as they age, changes occur in the composition, as well as in the intensity of the light emitted. In view of the importance of the spectral composition of light in many physiological processes in the plant, it is, of course, more difficult to generalise from results obtained under these conditions and to extrapolate to the behaviour of daylight-grown plants—a fact which may or may not matter, according to the problem under investigation.

The design of growth chambers in our Unit represents a compromise between these extremes. Since the plants are grown in daylight (with supplementary artificial light in winter), there is no strict control of light intensity, but neither are there gross differences in spectral composition from natural illumination. On the other hand, temperature and day-length are fully controlled and the controlled space is occupied solely by the experimental plants; that is, no accessory space for the operators needs to be controlled. This design has proved its worth in the last five years. As stated in the earlier article in DISCOVERY, the Australian phytotron will use this type of equipment on a very large scale indeed and thus differ from all other installations.

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W. W. SCHWABE

ARC Unit of Plant Morphogenesis and Nutrition,
Rothamsted Experimental Station,
Harpenden, Herts.

Erratum

We regret there was an error in Mr C. Scott's Letter to the Editor (DISCOVERY, May, vol. 20, p. 225). Line eight should read "... to memory errors by the respondent. . . ."

FAR AND NEAR

Science in Parliament: February 23–March 20

Among a wide range of Parliamentary Questions of scientific interest were two of current concern—radiation and fog research. Anxiety was expressed (February 23 and March 9) about the level of strontium-90 in wheat from the U.S. and the absence of examination of imported foods at ports for radioactivity. Government spokesmen in reply gave reassuring information on the lack of risk involved. Similar reassurance was given regarding drinking-water (February 26) and ionising radiation from the atmosphere (March 12); also there was news (February 25) of a new draft of safety regulations dealing with radiation in factories. As for research into fog-dispersal over small areas (March 16 and 18), news was promised of further developments with FIDO, while preliminary investigations had also been undertaken by the Meteorological Office into extracting moisture from the air.

March 4 saw an Adjournment Debate on the Jodrell Bank telescope. Back-bench speakers were critical of Government parsimony in the matter of this unique achievement of British science. It was recalled that the original estimate was for expenditure of £336,000, but the ultimate cost was £700,000; that Manchester University had been criticised by the Public Accounts Committee in this regard, and that whereas with increased grants from the DSIR and the Nuffield Foundation, £560,000 of this cost would be covered, the University would have to find the balance. For the Government it was stated that while they applauded the scheme, they were bound to adhere to the principle that a Government had to agree expenditure before being held liable.

Their lordships debated secondary education on February 26. This debate was disappointing in its infrequent references to scientific education; it did, however, give the Lord President an opportunity for presenting impressive statistics on the growing number of advanced-level passes in the GCE examination in scientific subjects and on outlay for science laboratories.

Many of Parliament's sittings before Easter are traditionally devoted to the Defence Estimates. The central issue was the deterrent and the nation's nuclear strategy—too vast a subject to deal with in these notes. However, the separate Service Estimates provided their quota of other scientific *pabulum*. In debating the Army Estimates (March 3) emphasis was placed on the result of research developments in re-equipment of vehicles, aircraft, small-arms, armour, radio-communications: the scientific education of officers was of vital importance and the status of the Royal Military College of Science was being raised. With the Air Estimates (March 5) came news of a wide range of technological advances—not least in the RADAR field. Disquiet was expressed by an Opposition spokesman on the absence of a comparable RAF institution to the Royal Military College of Science, while a short scientific course for general duty officers was needed. There was also criticism of a lack of clarity in the purpose of the *Blue Streak* missile: was it chosen as a strictly military weapon or for its potential in space-research? Finally the work of the Royal Naval Scientific Service, particularly with underwater weapons and detection, was stressed in discussion on the Navy Estimates (March 9).

To conclude, reference in a Supplementary (March 11) to "some Martian saucer" above London Airport elicited in reply that "there was insufficient evidence to determine what the cause of this light [*sic*] could have been!"

Science in Parliament—March 23–April 17

During this period numerous questions were asked on the activities of various branches of the DSIR: the work of the Radio Research Station, the building programming and flue distortion work of the Building Research Station, departmental responsibility for the Road Research Laboratory and its work in developing a skid-resistant tyre, progress and responsibility for research into diesel and petrol fumes.

A written answer (April 16) elicited the important news that the Minister of Power had appointed a committee to review developments in the use of coal as a basic raw material and to make recommendations for future research. News was given (written answer, March 25) that the National Lending Library for Science and Technology would be fully operational in 1962 at an estimated annual cost of £280,000: a Russian translating programme had already been started.

A large number of questions and an adjournment debate showed the Commons' concern about radiation level. Special reference was made to radioactivity in the London area (March 26). Speakers raised specific points relating *inter alia* to the disposal of radioactive waste, the organisation of monitoring for radiation, the role of local authorities regarding these problems, and the instruction of Public Health inspectors. A Government spokesman, replying, gave details of Britain's unique system of monitoring for radioactivity. This was on a national basis, and the programme's coverage included radiation in the atmosphere, debris which had fallen on the ground, drinking-water, milk supplies, and some imported foodstuffs. Details were given of reassuring results from this programme. Despite valuable work done by the LCC, it was right that this monitoring should be a national service. However, the Government would be meeting the local authorities to consider the possibility of a new code of legislation on radioactive waste.

Wednesday, April 8, saw a debate in their Lordships' House on crime and penal practice, during which news was given that the Wolfson Foundation were donating £150,000 for a Chair of Criminology and a Readership in connexion with the new Institute of Criminology at Cambridge. While this was a non-partisan debate, the Government's critics expressed concern at the inadequate research hitherto devoted to criminology: for instance, two years ago the Home Office was making grants of only £3000 per annum for outside research! Though tributes were paid to the valuable work of the Home Office Research Unit, it was suggested that its activities might be circumscribed by the smallness of its staff, which compared unfavourably with that of other research organisations. While progress with the Institute of Criminology at Cambridge was welcomed, time would be required before research there produced results; little initiative had been shown in this field by the University of Oxford. The Government spokesman announced a grant over the next three years to support the development of criminological studies in the University of Cambridge, and in reply to criticisms emphasised the wide-ranging programme of the Home Office Research Unit and the financial assistance to the universities and other bodies.

Finally, welcome news in both Houses (April 7): after a year's deliberations, the appointment of a Scientific Attaché to Moscow.

Canal to Link Volga with Baltic

Work has begun on the construction of a Volga-Baltic waterway which will link the main canals and rivers of the centre, the south, and north-west of the European part of the U.S.S.R. in a single deep-water transport system.

The new 224-mile canal, which will be completed under the Seven-Year Plan, will pass near the ancient Mariinskaya system, built at the beginning of the 19th

century, which cannot be used by big ships.

Six hydro projects will be built along the canal. Hydro-electric power stations will be erected on three of them: the Vytegorsk, Belousovsk, and Cherepovets.

The six reservoirs planned along the route of the canal will have a total surface area of 673 square miles. The largest of them, the Cherepovets, will be some 140 miles long.

Two hundred and seventeen inhabited localities are now being moved from the flooding zone to other areas.

New Service by the Atomic Energy Authority

An Information Centre has been opened at 11 Charles II Street, the London office of the United Kingdom Atomic Energy Authority to provide a convenient centre in London where members of the public, commercial firms, and other organisations may consult published unclassified material (that is with no security restrictions) and seek advice on sources of information on United Kingdom atomic energy matters.

The Centre forms part of the Public Relations Branch of the Authority. The facilities which it offers are complementary to the already well-established information services provided by the Authority at Harwell, Risley, and, to a limited extent, Aldermaston, for dealing with scientific and technical inquiries.

Next to the Centre is a Photographic Library which holds a collection of some 8000 photographs covering many aspects of atomic energy. Prints may be purchased out of stock or ordered to suit particular requirements. The library also holds stocks of slides in both colour and black and white which are available on loan.

Computer for the Japanese Weather Bureau

The tracking of typhoons, the age-old enemy of the Japanese islands, and other weather problems, will be the task of an IBM 704 computer, which is completing a 10,000-mile journey from New York to the Japanese Meteorological Agency in Tokyo.

This is the first computer to be used for daily weather prediction outside the U.S.A. It will co-operate with the U.S. Weather Bureau in Washington to conduct weather studies for the entire northern hemisphere.

Weather services throughout the world send up balloons twice a day to measure barometric pressure, temperature, wind velocity, and other data. This information is exchanged with other countries by means of teletype or radio, and forms the basis of world-wide weather predictions. In addition, data from other sources—for instance, the daily weather reports which every Japanese fisherman is bound by duty to send—is collected by the weather bureaux.

All this information is fed into the computer. The speed with which the vast amount of information is processed and with which calculations are carried out, makes longer-range forecasting possible than by manual means. The U.S. Weather Bureau is already able to make good forecasts forty-eight hours in advance.

In plotting the path of a typhoon which moves at great speed, devastating an area 100 miles wide in its course, there is seldom time for extensive manual calculations.

200-YEAR-OLD JAR OF PICKLES

The Food Research Association at Leatherhead was recently given a jar of pickles believed to be 200 years old. For many years a Shrewsbury grocer has been using the jar as a door-stop. The Association will open the jar, which weighs 11 lb. and is 18 in. in height, in their Leatherhead laboratories.

UNESCO Sponsorship of Marine Science Research Ship Proposed

A proposal that UNESCO should sponsor an international research ship was strongly supported by a group of international marine scientists at a three-day series of meetings at UNESCO Headquarters, Paris.

The meeting was called to discuss UNESCO's role in promoting international co-operation for oceanic exploration and was attended by consultants from scientific organisations in Australia, Denmark, Finland, France, the German Federal Republic, Italy, Netherlands, Norway, Poland, Sweden, the United Kingdom, the United States, and the U.S.S.R.

The ship, it was pointed out, would supplement research already being carried out on a national basis by some of the larger countries and could also tackle oceanographic problems that cannot be undertaken by the existing ships.

To meet this task, it was suggested that the ship should be 1200 or 1300 tons and be about 220 ft. long. Laboratory space would be provided for six permanent scientists and additional accommodation for fifteen visiting experts and students in training.

A supplementary proposal recommended that UNESCO should operate a number of chartered research ships on an international basis.

Emphasising the importance of increasing the food resources of the world by development of the oceans' potentialities, the consultants also urged that UNESCO and the United Nations Food and Agriculture Organisation (FAO) should draw the attention of all governments to the importance of marine research.

Further specific aid was requested from UNESCO in the form of research contracts for individual workers and laboratories, fellowships for training purposes,

FAR AND NEAR—*continued*

travel allowances for scientists participating in international co-operative projects, the assignment of experts to countries requiring technical assistance in this field, and the provision of equipment and facilities for co-operative projects between countries.

Council of Europe Competition

A new competition with a prize award of one million French francs is announced by the Secretariat-General of the Council of Europe.

The prize is to be awarded every two years for a thesis on a given subject of European importance. The subject chosen for the first competition is "Consequences of the use of nuclear energy for the European mode of life".

The Secretariat-General has stipulated that the work presented must be "of a high academic standard. It must not have been previously published, and must represent an original contribution on the subject."

Theses may be written in English, Dutch, French, German, Italian, or Spanish and entries must be submitted before the end of 1960.

Further information may be obtained from the Secretariat-General, Council of Europe, Strasbourg, France.

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